January 2005 • NREL/MP-510-37240

Multi-Year Technical Plan for Ethanol

March 31, 1997

J. Sheehan

National Renewable Energy Laboratory
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Office of Energy Efficiency and Renewable Energy
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"The Road to Wisdom"
by Piet Hein

The road to wisdom? Well, it's plain and simple to express:

Err
and err
and err again
but less
and less
and less

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1. Preface

This is the second version of the multi-year technical plan for ethanol (more affectionately known as the MYTP). The basic plan was first issued in October 1996. At the request of the Office of Fuels Development, we have reissued the plan, this time with a complete set of resource estimates for all activities in the plan. Resource loading is a tricky thing to do. It is difficult to estimate the work requirements for these activities, except by intuitive guessing loosely based on experience.

By actually putting these estimates of work on paper in this plan, we have begun the process of learning better how to estimate the work that is required for all of the R&D activities listed in the plan. But, we will only get better at this if we begin to track what it actually takes to do the work in our plans and use such feedback to refine our estimates. Today, we do not have that capability. Our budget and tracking systems are not organized along the same lines as the MYTP. Therefore, if this plan is to be more than an isolated exercise, we need to re-look at our tracking systems so that we can actually "learn" from our experience.

As you look at this plan six months after it was originally issued, it will be apparent how much of it is already "wrong." No doubt much of the plan was wrong as soon as it came off the presses. Therefore, many will be inclined to dismiss this plan and move on. I hope that we will not do that. There are many valuable lessons learned from the exercise of resource loading the plan. This effort has pointed out many deficiencies in our thinking. I hope that we will apply these lessons as we move into the new planning efforts this year.

The essence of strategic planning is, I firmly believe, trying to systematically look at the big picture and, through that process, guess about the next steps we must take. The poem that is included at the start of this report is one cited by Dr. George Steiner, one of the renowned names in strategic planning. I believe that we can learn to err "less and less" as we continue the planning process initiated in this report.

John Sheehan
Biotechnology Center for Fuels and Chemicals
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April 1997

2. Executive Summary

2.1 What's New in the Plan?

Much has been done to the plan since its first delivery to the U.S. Department of Energy's Office of Fuels Development (OFD) in October 1996. Many of the issues and concerns about the plan raised by OFD as a result of its initial review have been addressed in this new version. These include:

- Addition and integration of a detailed feedstock development plan for switchgrass
- Discussion of the rationale for selection of model feedstocks based on our understanding of similarities and differences among potential near term feedstock sources
- Estimation of all resource requirements for the plan
- Year-by-year budget estimates for the program
- A comparison of existing and required resources to meet the baseline plan for conversion technology development
- A resource-leveled plan based on current estimates for staffing of the conversion technology aspects of the plan
- A critical path analysis of the year 2005 goal for deployment of switchgrass-to-ethanol technology
- And, finally, a glossary of terms

There are some concerns and requests which OFD made last Fall which have not been adequately addressed in this version of the plan. The key issue is partnership development. While the baseline plan itself does include all aspects of the Partnership Development Team (PDT) plan, OFD requested that we more thoroughly integrate the PDT plan in the MYTP so that the MYTP would fully represent, in one document, the program's activities for deployment of bioethanol technology. Integration was to include all text and strategies spelled out in the PDT plan. This has not been done beyond the level at which it was done in October 1996. One process technology development plan is needed for the Bioethanol Project. NREL will utilize the "stage gate process technology" approach to accomplish this goal.

Finally, for those who are really into metrics, we can say the following:

In October, 1996, the full bioethanol Gantt chart ran 6 feet in length when assembled in one sheet. This version of the plan extends to just over fifteen feet!

2.2 Goals and Objectives

The Biofuels Program at the National Renewable Energy Laboratory has completed an eight-month effort to develop a detailed, fully resource-loaded multi-year technical plan for the deployment of bioethanol technology. This plan addresses the specifics of what it will take to achieve the following two goals:

Year 2000 Target

Commercial demonstration scale production of ethanol will be on line by the end of the year 2000 for one or more of the following waste feedstocks:

Wood wastes/residues

Grain processing wastes

Year 2005 Target

Commercial demonstration scale production of ethanol will be on line in the year 2005 which utilizes switchgrass as a dedicated energy crop as part or all of its feedstock supply

Multiple iterations of input and feedback were completed to establish the targets, associated technical performance objectives and the details of the plan itself. Stakeholders from NREL, DOE's Office of Fuels Development, Oak Ridge National Laboratory and from outside the program were involved in the development of the plan.

2.3 The Baseline Plan

The plan is based on an assumption of level funding for the foreseeable future. The schedule includes linkages among all major elements of the program, including:

1. Feedstock Development
2. Biomass Conversion Technology Research and Development
3. Partnership Development and Commercial Deployment

Research and development activities on the biomass conversion technology are conducted by the Program through bench scale integrated testing. Pilot scale testing of the technology is then the responsibility of a partnership-driven effort. In the overview chart, this critical tie-in is shown occurring in the business plan stage of a partnership.

This is an important separation of responsibilities. The final choice of feedstocks and technology to be tested at the pilot scale will be determined by the needs of the industrial partner, based on business plans developed prior to pilot scale tests. The plan assumes that core technology for conversion of biomass to ethanol developed under the Biofuels Program will be available to partners. This technology will be one of a number of options that a partner can consider, including technology developed elsewhere. Likewise, the plan assumes that the Alternative Fuels User Facility will be available for use by partners, if desired.

If the year 2000 target requires current NREL conversion technology development (as we have assumed in the plan), start-up of the demonstration plant will be in late 2000 or early 2001. An ASPEN™ process simulation was used to incorporate all of the technical performance objectives which we believe can be met in time for our first deployment target. This model indicates that ethanol can be produced at a cost of $1.13 per gallon assuming access to waste feedstocks costing no more than $15 per dry ton. As shown in the plan, however, current partnerships with the City of Gridley in California and with Amoco, if completed on schedule, might actually allow us to meet the target as early as 1998.

Switchgrass-to-ethanol technology deployment occurs in early 2006. We have not completed cost analyses at this time to assess what the price for ethanol in the year 2006 could or should be. Instead, we have assumed that the technology development efforts for both switchgrass production and conversion will be able to achieve a market-based goal of $.90 per gallon for ethanol used as an oxygenate and octane enhancer.

The switchgrass plan has been greatly improved in this second version of the MYTP with more detail on the development of switchgrass production technology. This shows up in two areas: 1) partnership development and commercial deployment activities for switchgrass producers, and 2) core technology needs for switchgrass production.

Partnership activities include market conditioning to get appropriate technical and economic information developed and in the hands of potential feedstock producers, as well as field testing to help producers gain experience with switchgrass as an energy crop.

Core technology support for feedstock production focuses on the establishment of four regional Crop Development Centers. Each of these regions will identify and screen the best varieties of switchgrass for their areas. Testing and scale-up of switchgrass production will be done in each region as well. Testing will include economic and environmental evaluations. Finally, the core technology effort includes a long term effort to improve and optimize switchgrass cultures. This work will continue beyond the initial deployment of switchgrass to ethanol technology.

2.4 Resources and Budgets

Resources and budgets for the multi-year technical plan have been established based on direct input from researchers in all the key areas of the program. The baseline plan was developed in the Fall with the assumption that funding would be relatively flat from 1996 through the foreseeable future. Thus, researchers initially guessed at the timing of future activities based on their current resources.

It turns out that most estimates were on the low side of this constraint. It is likely that these cost projections are very low due to the tendency to be too optimistic in assessing resource requirements and our

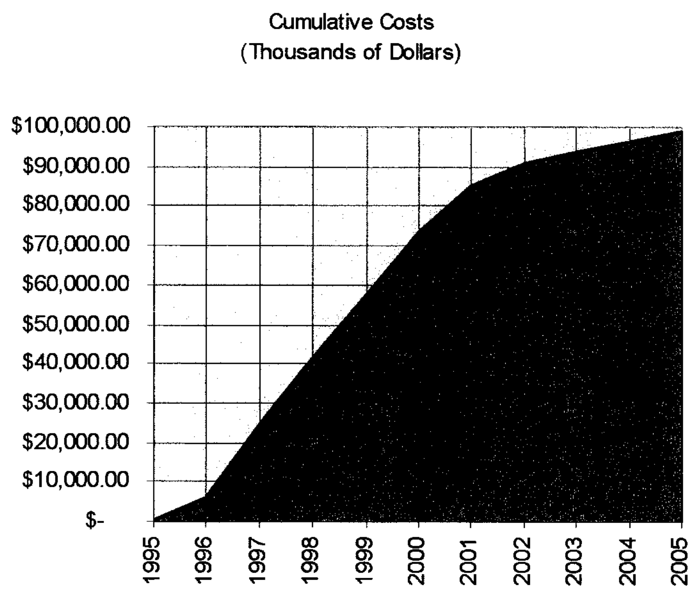


Figure 1: Total Cost for Near and Mid Term Deployment Goals

It is anticipated that funding needs for the long term technology will ramp up early in the next century.

Another major assumption in these costs is that DOE contributions to capital and start-up costs are on the order of 10% (*i.e.*, that DOE money is leveraged 10:1 with industry). It remains to be seen whether or not this is realistic.

general lack of experience in projecting such costs.

The total cost of meeting our deployment goals for the years 2000 and 2005 is $83 million. Allowing for inflation, this amounts to just over $100 million in annual appropriations.

Spending on an annual basis runs from a high of $18 million in 1997 to a low of around $9 million in 2001. This is the period of critical activities for the two deployment goals outlined in the plan. After that point, DOE funding drops dramatically as more of the cost is picked up by industry partners.

However, it is important to note that...

... the cost projections shown here do not include the cost of R&D support of long term hardwood feedstock technology.

The preliminary comparison of resource needs versus current availability for conversion technology R&D done for this plan suggests that...

... all of our resources are pushed well beyond current levels for the next two years.

This has very important implications for our ability to meet both the mid term and long term goals. If our current resources are kept the same, we can expect significant delays in the deployment. The solution to this problem is either to increase resource allocations (difficult in tight budget times); or, to reduce the scope of our plan, particularly in the near-term where the bottleneck is most severe.

Using relatively rudimentary resource-leveling tools available in Microsoft Project™, this report shows that...

... the current resource limitations will force us to delay near term deployment of waste cellulose to ethanol technology until the year 2004 if we continue with the plan as it has been developed. Likewise, switchgrass deployment is delayed until the end of 2008.

Furthermore, there is not just one area or type of resource that is over-allocated. All of the resources considered showed varying degrees of over-allocation in the first two years.

These results probably reflect worst-case thinking. Since resource-leveling in Microsoft Project™ is rather unsophisticated, it is likely that the software has over-estimated the delay. The lesson to be learned here is that we do face a conflict between planned activities and resources to support them.

2.5 Critical Path Analysis for the Year 2000

A preliminary critical path analysis was done in the October 1996 issue of the MYTP. We have revisited this analysis, and have considered critical paths for both the original plan as presented in October and the resource-leveled plan.

For the original baseline plan (prior to resource leveling the plan), we identified a series of critical items in the plan. These include:

- Partnership development activities for softwood technology and the Delta-T CRADA
- The PDU testing and negotiations steps in business plan development
- All start up and construction aspects of the demonstration plant
- The entire softwood technology development effort under core technology
- Development of detoxification technology
- Integrated testing of the final SSCF process

Business plan activities and design and construction of the demonstration plant will always be on the critical path to the final deployment goal. As the definition for critical tasks is expanded to include "non zero" float activities, integration activities become pivotal. These are the types of activities that we would expect to be critical. It shows that the basic plan itself has sound logic, though it is not well aligned with our current resource assignments.

It is clear that process integration work is the first critical path activity that must remain on track.

The resource-leveled plan only shows the final construction and permitting as being critical. This is telling us that our resource assignments are completely out of line. The current resource assignments lead to a situation in which everything in the R&D and partnership plans have excessive slack. This is a sign of a very inefficient plan.

2.6 *Critical Path Analysis for the Year 2005*

Critical activities identified within the baseline plan include the following:

- PDU testing of integrated technology
- Negotiation and final business plan development
- All demonstration activities supporting both the agricultural production and the feedstock conversion technology
- Roll-out of second technology improvements for near term technology
- Integration of technology for conversion of switchgrass
- Within applied research, the entire set of activities required to develop countercurrent prehydrolysis technology are in the critical path
- Also, a variety of activities within enzyme, fermentation organism, and lignin technology development are critical

It makes sense that, for the mid term technology, we would see more critical tasks within the core technology areas.

The main critical path remaining in the plan after leveling of resources starts with the PDU scale testing of the switchgrass conversion technology and continues through demonstration steps for the agricultural production and conversion technology.

Beyond this section of the plan, process integration and some aspects of the fermentation organism development effort that affect the critical path

2.7 *Critical Issues and Conclusions*

There are many flaws with the plan presented here. For that reason, we must be careful not to take the detailed conclusions too literally. Just to cite a few of these flaws:

- Resource estimates are "ball park" figures
- NREL has little data to support or provide feedback on our resource estimates
- The plan is not necessarily consistent with the FY 1997 Annual Operating Plan already in place for conversion technology development.
- The thinking that went into this plan is now six months old and is out of date

Within these limitations, the plan does still highlight some very important issues. These include the following:

- The current plan faces a serious bottleneck in resources
- This bottleneck can only be resolved by better identification of priority, value-added activities
- Increasing resources does not necessarily address facility limitations such as the Ethanol PDU

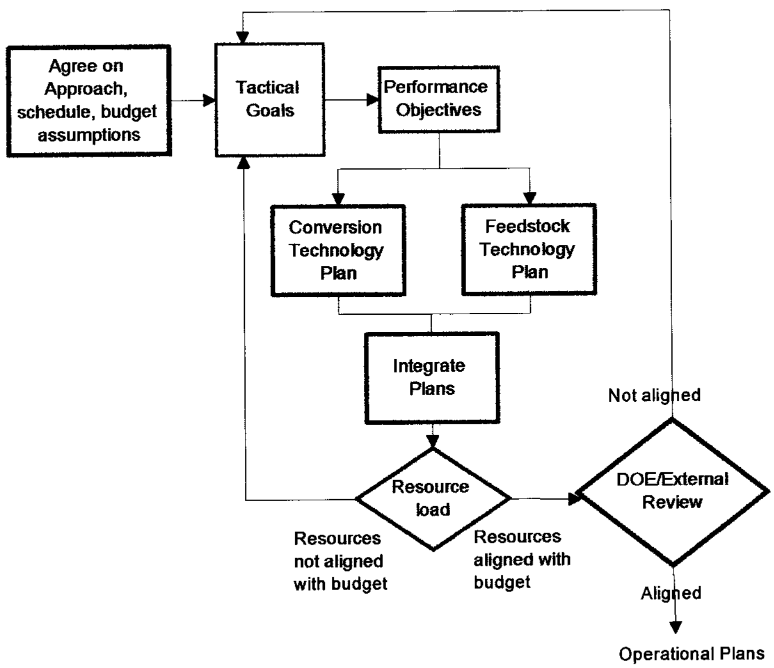
If this plan is to be of real use, there are a number issues which should be addressed down the road. The most important one is to tie the plan to accurate process economics. Plans to do this have been developed, and are already underway. This is especially true in the assessment of research plans supporting the year 2005 deployment goal, where no attempt has been made to translate research results into quantitative economic results.

Furthermore, an effort should be made to revisit the plan as soon as possible in order to bring it in line with the latest thinking of researchers. Through a combination of process analysis and planning, we should revise the current MYTP prior to conducting detailed planning for the FY 1998 annual operating plan. The current plan is of little use since it cannot be used as a tracking device against the current activities. The reason that this plan cannot be used for tracking is because the current annual operating plan was developed independently of the MYTP. We should avoid such disconnects in the future.

3. Background. How we developed the plan.

The process of establishing the ethanol multi-year technical plan has not been a simple one. A flow diagram describing the process we are going through is shown in Figure 2. The first three steps involved a series of discussions with DOE, NREL and Oak Ridge staff. The key issue for setting these tactical goals was the choice of feedstocks to be targeted. ORNL, NREL and DOE staff quickly came to agreement on switchgrass as the mid term feedstock. An analysis of near term waste feedstocks was conducted and used as a basis for surveying DOE, ORNL and NREL staff to set priorities on the waste feedstock opportunities for deployment in the year 2000.

Figure 2: Process for Developing the Multi-Year Technical Plan



Once the broad tactical goals for deployment were agreed upon, we focused on more detailed discussions with NREL staff on the specific technology performance objectives for the biomass-to-ethanol conversion technology. The premise of these discussions was what was technically feasible for both the near-term and mid-term targets. In other words, our discussions with NREL researchers resulted in a list of performance targets for each area of the technology. For feedstock technology development, this meant establishing production capability for switchgrass at a cost of $42 per ton. Waste feedstocks for the year 2000 were defined arbitrarily as those feedstocks costing less than $15 per ton.

Performance targets for conversion technology are being used to determine an achievable price target for ethanol using our ASPEN™ process model and Questimate™ cost prediction software. So far, only the year 2000 targets have been translated to an ethanol price target. More involved changes to the ASPEN™ model are needed before we will be able to report on cost targets for the year 2005.

A secondary issue always in the background of our target discussions was the question of what product price target is required for our technology to compete in the market place. We have not actually connected the technology development-based target with a market analysis to determine if the feasible price target matches the price requirements for ethanol market penetration goals in the year 2000. Further iterations of the plan will be required to achieve synchrony between the multi-year technical plan and market-driven targets.

Feedstock development plans were established independently by researchers at Oak Ridge National Laboratory.

Revising NREL's plans to meet the technology performance objectives involved a series of meetings with NREL researchers in which detailed steps for attaining goals in each of the following areas were prepared in advanced:

- Process integration
- Chemical prehydrolysis and complete hydrolysis
- Enzyme R&D
- Fermentation strain development

The focus of the discussions was on core conversion technology development at NREL. For our near term goals, this corresponds to our work on hardwood sawdust. In the mid term, this involves switchgrass.

Each area listed above presented their plans and estimates for time and resources. The activities for each area were posted on a wall-sized time line with the year 2000 and 2005 deployment targets marked on it. With these detailed activities in place, we were able to identify what technology improvements would be ready in time for the near term and mid term targets. In addition, we identified interactions and handoffs which needed to occur among the different areas. Once we agreed on all the necessary interactions and timing for technology development, the next step was to translate this wall-sized plan into Microsoft Project™.

Plans for partner-based activities were put together in parallel, but separate, efforts. These include:

- Softwood technology deployment
- Grain processing opportunities with CRADA partners
- Partnership development

The first two items represent plans for near term deployment of the two other feedstocks identified as high priority near term opportunities. They are not, however, part of the core technology development effort centered around hardwood sawdust. Gantt charts for these partnership activities were integrated into the core technology plans developed by NREL in-house researchers. Finally, all of these activities were tied to deployment-related plans for the near term and mid term goals. A complete Gantt chart was distributed to team leaders as an outline for drafting the descriptions of the activities included in this report.

The conversion technology plan was integrated with feedstock development activities being planned by Oak Ridge National Laboratory. Interactions between the feedstock and conversion technology plans were established, along with detailed Gantt charts and write-ups for the feedstock efforts. The feedstock plan was then fully integrated with the conversion technology plan to form a comprehensive ethanol technology deployment plan.

The first draft of our multi-year technical plan was then submitted to a review process both by our customers in the Office of Fuels Development and outside stakeholders. We purposely skipped the resource-loading step due to time constraints. The comments from these two groups were comprehensive and substantive. They led to significant changes in the plan from its first draft. This plan is much stronger because of the valuable suggestions and concerns raised by these two groups.

In this second version of the plan, we have gone back to the resource-loading step to see how the plan translates in terms of cost and available resources.

4. Tactical Goals for Ethanol Deployment

The background section has already alluded to elements of the tactical goals established for the ethanol program. For the sake of clarity, they are explicitly stated in the following sections. These goals refer to commercial demonstration facilities, which we envision to be at a scale of at least several million gallons per year of bioethanol production.

We are not assuming that these facilities will necessarily be grassroots operations (i.e., that they will be new plants). Our analysis of the cost of production is based on a grassroots facility. It shows that capital costs are a significant element in the total cost of producing ethanol. The first demonstration scale facility may well be a retrofit of an existing ethanol facility. Such a facility could produce ethanol at a more competitive price than our projections indicate based on the performance targets that have been set. Finally, the cost model presumes fairly conventional approaches to financing. More creative financing options and unique opportunities for financing could dramatically reduce the cost of capital.

4.1 Near Term (Year 2000)

Commercial demonstration scale production of ethanol will be on line in the year 2000 for one or more of the following waste feedstocks:

- Waste softwood
- Hardwood sawdust
- Grain processing wastes

Given the limited resources available for development of ethanol conversion technology, it is important to develop an approach that is efficient as possible. We have, therefore, focused technology development in the near term on one model feedstock, rather than on each of the feedstock types identified above. We must be certain, however, that such an approach is appropriate. The following section addresses our rationale for identifying a model feedstock for use in core technology development

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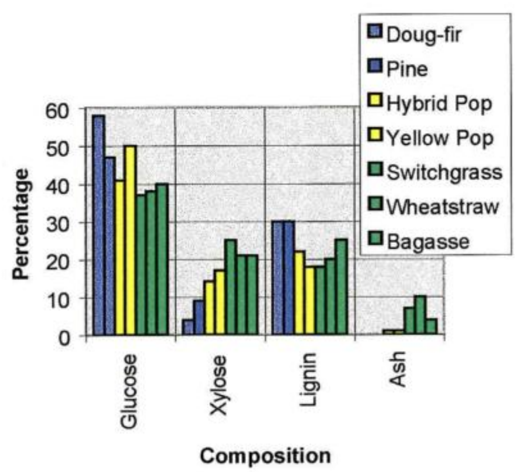


Figure 3: Comparison of Major Feedstock Classes

4.1.1 Selection of a Model Feedstock for Near Term Core Technology

Baseline biomass feedstocks are those feedstocks that represent a resource capable of providing enough raw material for the biomass-to-ethanol process, on a national scale, to facilitate meeting the Biofuels Program's ethanol production goals. If this definition is accepted, than niche feedstocks are not directly considered in the selection of baseline feedstocks. Still, it is clear that, in the near term, it is niche feedstocks that will provide the first entree into the market place for bioethanol. Thus, in our selection of a model feedstock, we have focused on choices that provide a bridge between baseline feedstock needs and near term market demand.

Niche feedstocks are associated with an existing industry and are low or negative cost byproducts from the processing of biomass into the primary product. Examples of niche feedstocks currently under consideration for various collaborative research opportunities are, corn fiber, pulp cake, rice straw, and spent grain. While these feedstocks provide an opportunity to establish early biomass-to-ethanol facilities because of feedstock cost and association with standing facilities that reduce capital cost, the amount of available feedstocks of this type are not great enough to supply a significant portion of the target production goals. In addition, ethanol production from most niche feedstocks depends on the development of a complete conversion processes. Even though, some of the more refined feedstocks (e.g., pulp cake and corn fiber) may provide opportunities to drop some of the steps in the conversion process.

4.1.1.1 Appropriate Classification of Feedstocks

In the past, biomass feedstocks have been classified as either waste and residues or dedicated energy crops. However, these classifications are based on where the feedstock originates and do not take into consideration the true structural aspects of the feed that ultimately affect the conversion process.

To properly classify feedstocks, a different approach should be employed. A more proper classification scheme is to separate feedstocks based on the major physiological characteristics of the plants from which they are derived: softwoods, hardwoods, and grasses. For all these major classes the source of feedstock is the vegetative structures of the plant. The structural composition of these three major classes varies more between classes than within classes. Figure 3 shows representative compositions for these three main classes (softwoods in blue, hardwoods in yellow and grasses in green). This has to do with the basic structural and cell physiology of the plants. While all complex terrestrial plant cellular structures consist of the same basic chemical components their proportion and physical combinations vary.

4.1.1.2 The Softwoods

The softwood category refers to tree species in the *Pinaceae* family. This family contains the pine, larch, spruce, hemlock, fir, and Douglas-fir genera. The wood of these trees is made up of one predominant cell type, the trachied. The composition of the tracheid cell structure differs from other plants because of the high levels of mannan and low levels of xylan. Also, the lignin content of pines tends to be high (see Figure 3).

Softwoods are the primary feedstock for most forest products in the U.S. This means that much of the pulp and paper mill waste, sawmill residues, forest residues, waste paper, and wood in municipal solid waste (MSW) streams has softwood cellular structures. This fact needs to be taken into consideration when assessing these feedstock resources.

Current pretreatment methods and fermentation technology have not been optimized for softwoods. The primary reason for this is that softwoods have not been seriously considered as feedstocks because of competition for the raw resource (trees); but, if waste streams are identified as niche opportunities (pulp mills and softwood sawdust) and mid-term resources, then this type of feedstock material can play a significant role in the success of the Biofuels Program.

4.1.1.3 The Hardwoods

Hardwood refers to trees in the *Dicotyledoneae* class of plants with true flowers. The wood consist of vessels, tracheids, and fibers. The composition of these cells are similar to those of the grasses, also dicotyledons. However, there are some significant differences between hardwood trees and grass composition because of plant structure. Trees use the carbon they capture during photosynthesis to build large plant structures (roots, stems, and branches) of wood that help them compete for light, water, and nutrient resources. The cells that make up the wood are dead and mainly consist of just the cell walls and the middle lamella that holds them together. These cellular structures are made of mostly glucan, xylan, and lignin. Hardwoods generally have similar amounts of glucan and lower levels of lignin compared to softwoods. Where softwoods and hardwoods really differ is in the amount of xylan and mannan. Hardwoods generally have high levels of xylan, and mannan is a minor polymer.

Like softwoods, hardwoods are used in making many forest products (paper, lumber, and furniture). Because of the fast growing characteristics and adaptability of some hardwood species, they are being developed as dedicated energy crops (*e.g.,* hybrid poplar). Thus, hardwoods can provide niche opportunities (pulp cake and hardwood sawdust) and middle to long-term opportunities.

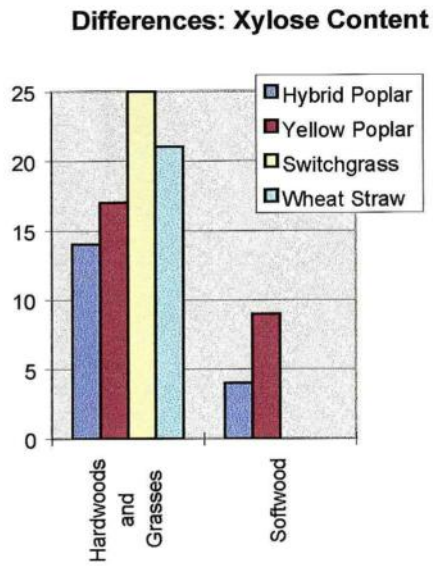


Figure 4: Xylan -- Softwoods as a Special Case

Hardwoods vary greatly in wood density, but are relatively consistent in composition. Work on the wood from a wide range of different hardwood species indicates that they respond well to acid hydrolysis and SSF. This fact has led to extensive use of wood from various poplar species in optimizing these procedures.

4.1.1.4 The Grasses

Major grass species that produce grains, sugar, and forage are dicotyledons. Thus, the composition of the cells that support the plant structure are very similar to those observed in hardwoods (Figure 3). The difference between the grasses and hardwoods is caused by a different growth/reproduction strategy. Annual grasses live only one year. These grasses die after producing seed. Perennial grasses live many years. The above ground structure of the grass dies after seed production, but the roots live and sprout new stems and leaves each year. Because the grass stems and leaves are actively growing they contain nutrients, simple carbon resources, and other chemical compounds necessary to carry on metabolic functions. This means that a significant percentage of a grass's dry weight contains extractives and ash not observed in the woody feedstocks. In addition, biomass from grass will tend to also contain reproductive structures that are made of primarily hemicellulosic materials. This is one reason why grass biomass generally contains more xylose and arabinose than observed in hardwoods (Figure 3).

4.1.1.5 The Similarities and Differences

Experience with corn stover and switchgrass demonstrates that the current biomass-to-ethanol conversion process steps developed using hardwood work equally well, if not better, on the herbaceous feedstocks. This indicates that both hardwood and herbaceous feedstocks can be converted using the same process.

In the case of softwoods, many of the conversion process steps developed from the current hardwoods based research should work. Figure 4 and Figure 5 show a comparison of hardwoods and grasses to the softwoods. These two charts demonstrate very clearly why work on a hardwood feedstock can be expected to translate well for switchgrass. At the same time, they show why we might well expect differences in the performances of processes optimized for softwood feedstocks.

4.1.1.6 One Model Feedstock or Several?

As the previous discussion implies, identifying a single feedstock as a model is not trivial. No single feedstock can completely represent process performance for both niche and long term feedstocks. We have settled on the use of hardwood sawdust model feedstock as a reasonable compromise. As a hardwood, it helps us to predict process performance for our ultimate long term feedstock (short rotation woody crops). At the same time the hardwood process is a very reasonable model for switchgrass. The question boils down to whether or not softwoods require their own model feedstock. Our experience with softwood and the composition data shown here support the notion that optimal conditions and performance of a softwood process will be different. Given the fundamental similarity of all of the lignocellulosic feedstocks (see Figure 3), we are talking about optimization of a basic technology platform as opposed to a fundamentally different process. For this reason, we believe that the work we are doing on hardwood sawdust for development of a basic technology platform can and should be our first priority before expending

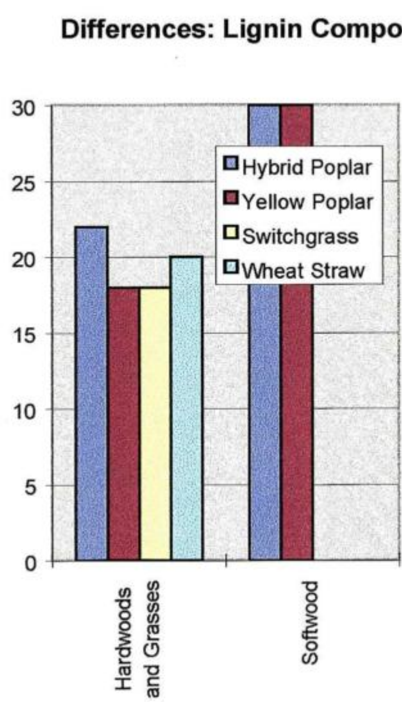


Figure 5: Lignin -- Softwoods as a Special Case

extensive resources on optimization for softwood feedstocks.

4.2 Mid Term (Year 2005)

Commercial demonstration scale production of ethanol will be on line in the year 2005 which utilizes switchgrass as a dedicated energy crop as part or all of its feedstock supply.

5. Conversion Technology Performance Objectives

Performance objectives were set based on our core technology. This refers to a process which can utilize hemicellulose and cellulose-derived sugars.

5.1 Near Term (Year 2000)

The process configuration for the near term demonstration facility is shown in Figure 6. Waste feedstocks will be subjected to a chemical prehydrolysis that will solubilize the hemicellulose fraction of the material and render the cellulose fraction more susceptible to enzymatic hydrolysis. Toxic components produced in the prehydrolysis step are removed before the biomass is sent to the fermentation step, which relies on an organism that can ferment both xylose and glucose sugars. A portion of the prehydrolyzed, detoxified biomass is diverted to enzyme production. Cellulase enzyme is continuously fed to the fermenter, where it hydrolyzes cellulose to glucose. Hydrolysis rate is enhanced because of the removal of sugars by the fermentative organism.

Table 1: Year 2000 Performance Targets: Prehydolysis

Solids Concentration to Reactor	35%
Acid Concentration	0.3%
Temperature	200°C
Residence Time	4 min
Xylose Yield	75%
Glucose Yield	8%

Table 1 shows performance objectives for prehydrolysis. These objectives are based on pilot scale performance of the Sunds® cocurrent pretreatment reactor in the Ethanol PDU.

Table 2 shows the goals established for detoxification of the prehydrolyzed biomass. The current process requires significant dilution of the biomass to mitigate toxicity problems in the fermentation. Because of the tremendous impact dilution can have, the near term goal

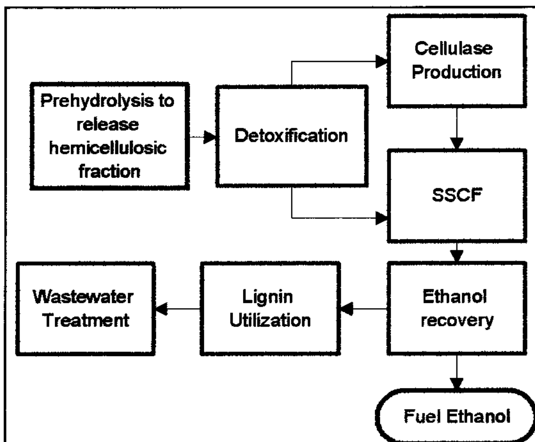


Figure 6: Process Configuration for Near Term Technology Deployment

is to eliminate dilution entirely by using an ion exchange process to separate toxins from the hydrolysis sugars.

Table 2: Year 2000 Performance Targets: Detoxification

Approach	Ion exchange with overliming
Dilution	None
Sugar losses	minimal
Removal of Toxics	Sulfuric Acid, Acetic Acid

Cellulase enzyme performance targets are shown in Table 3. They are based on the use of existing *T. reesei* production technology. Existing cellulase production is the only viable option for production of enzyme in the near term.

Table 3: Year 2000 Performance Targets: Enzyme Production and Use

Enzyme Yield	50 to 100 FPU/gr cellulose
Enzyme Loading	18 FPU/gr. cellulose for 7-day fermentation
Temperature	28°C
Productivity	55 FPU/l-hr

We anticipate improving performance of the enzyme by developing improved protocols for enzyme induction that are based on the actual feedstocks used in the ethanol facility.

Table 4 shows targets for the fermentative organism based on our work with the genetically engineered *Zymomonas* strain.

Table 4: Year 2000 Performance: Fermentation Organism

Organism	Zymomonas
Substrates	Glucose, Xylose
Temperature	35°C
Residence Time	7 days
Xylose-to-Ethanol Yield	85%
Cellulose-to-Sugar Yield	80%
Glucose-to-Ethanol Yield	90%

5.2 Mid Term (Year 2005)

The key change in process performance overall in the mid term deployment of bioethanol technology is that it will be able to accommodate switchgrass as a feedstock. This means that process improvements must offset the increase in feedstock cost from $15 per dry ton for waste feedstocks to $42 per dry ton of switchgrass.

Definition of the mid term technology is more difficult. The process configurations anticipated involve several options, depending on the outcomes of research in chemical hydrolysis and enzyme production. The major bifurcation in the development of this process would occur in the chemical hydrolysis step.

Here, two main approaches are being investigated:

- A complete hydrolysis step that obviates the need for cellulase enzymes, and
- A second generation prehydrolysis

There is also a possibility that we will end up with a process that is a hybrid between prehydrolysis and complete hydrolysis in which a portion of the cellulose is hydrolyzed to sugar, but enzymes are still required to hydrolyze the intact cellulose coming out of this step. The second major bifurcation could occur in the enzyme production step. We will pursue two avenues for cellulase production:

- crop-based production of cellulases, and
- Submerged culture production using genetically engineered organisms

Both approaches would require the development of improved cellulase systems. They represent two approaches to expression of the cellulases.

5.2.1 Chemical Prehydrolysis and Full Hydrolysis

Between the year 2000 and year 2005 deployment targets, we will introduce countercurrent prehydrolysis technology that is capable of achieving much higher yields of hemicellulosic sugars (increasing from 75% to 95%). While the initial roll-out will require detoxification, we hope to target a process which eliminates this type of step in 2005. By the year 2005, we will also have evaluated the complete hydrolysis route. This option would have to provide the same high yields and lead to a 91% conversion of the total sugars without toxic inhibition.

5.2.2 Cellulase Production

The overall target for cellulase production is to reduce the contribution of cellulase cost to around $.10 per gallon of ethanol produced. This represents a three-fold improvement in cellulase technology compared to the year 2000 deployment target.

Achieving this target involves two approaches:

- Improving specific activity of the cellulase system, and
- Reducing production cost for the enzyme

A combination of these two efforts will be needed. In other words, we could meet the target through a three-fold increase in cellulase specific activity; but such a jump is unlikely. We might achieve a two-fold increase, with the remaining cost reductions coming from improvements in enzyme production technology through submerged culture or crop technology.

5.2.3 Fermentation Strain Development

Targets for fermentation development include the following:

- Development of a robust organism which operates at conditions of pH and temperature that are less susceptible to contamination

- Ability to ferment switchgrass sugars
- Temperature compatible with cellulases (45 to 50 Celsius)
- pH of 3.5 to 4
- Two-day fermentation time
- No glucose repression

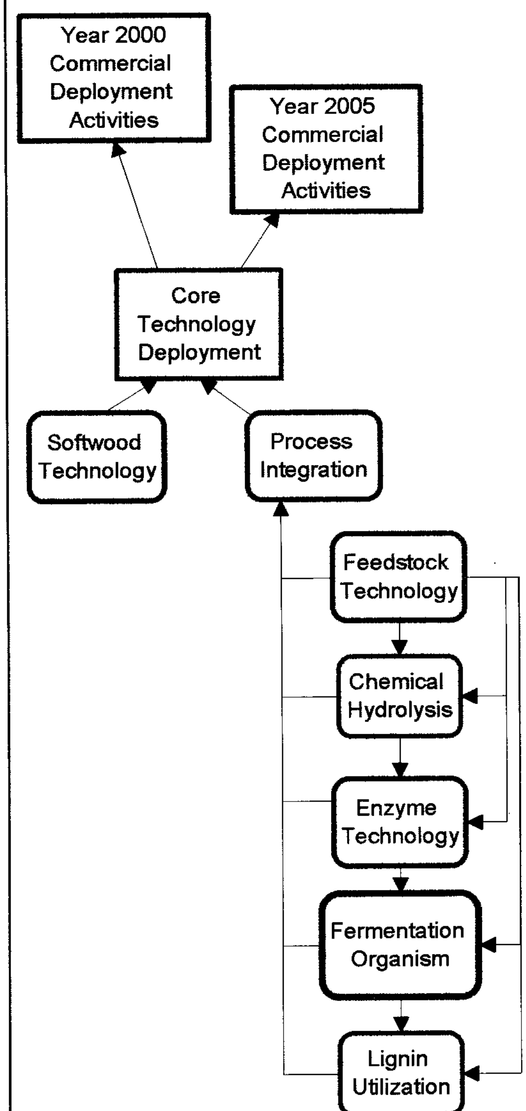
6. The Plan

It is important to understand the organization of the plan as shown in the Gantt chart attached to this report. It is divided into a number of major types of activities. A flow chart is shown in Figure 7 as a guide to the plan.

The first two major sections of the plan cover deployment related activities for: 1) the year 2000 commercialization target; and, 2) the year 2005 target. The plan carefully distinguishes deployment activities from core technology development. This is because the nature of deployment as an activity inherently implies the involvement of an industrial partner capable of taking the technology to the marketplace. It is not the job of the U.S. Department of Energy or its national labs to accomplish this transfer.

We will likely continue to struggle with where this transfer of responsibility should occur. In this plan, we have assumed that, once the bioethanol technology has reached the need for pilot scale demonstration, it must be driven by an industrial partner whose market-specific needs are fully integrated into the scale-up. This means that scale-up will be done within the constraints of the partner's choice of feedstocks and the economics of the that partner's application. The deployment effort also involves the development of a comprehensive business plan done primarily by the industrial partner.

Figure 7: Flow Chart for MYTP



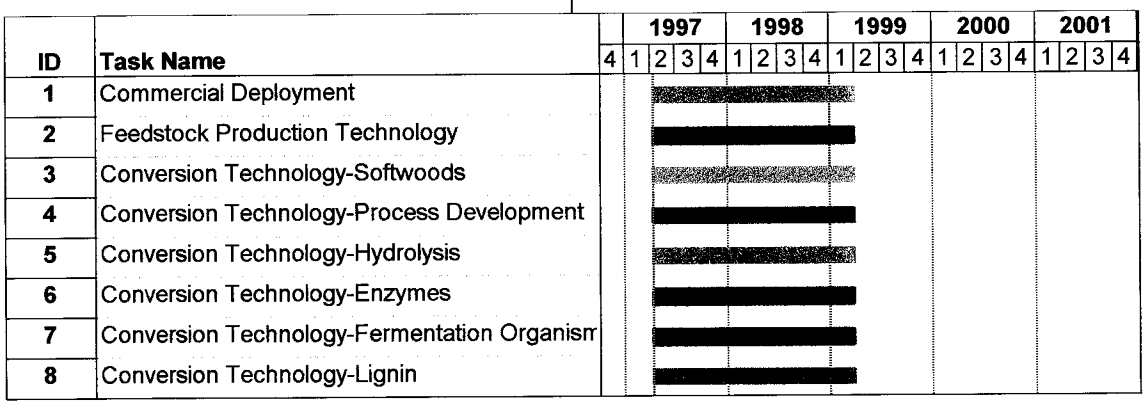


Figure 8 Color Coding of Baseline Plan

The remainder of the plan includes details on the development of core technology for conversion of biomass to ethanol and for production of biomass feedstocks. The core technology development for feedstocks is focused on switchgrass. Research and development activities for conversion technology includes chemical hydrolysis, enzyme production, fermentation and lignin utilization, all of which feed into a process integration activity.

We have introduced a wrinkle in this breakdown of the research to deal with specific issues related to softwood feedstocks. Technology development for utilization of softwood relies heavily on the development activities for core conversion technology because it utilizes all of the same process technology elements. Since near-term opportunities for utilization of softwoods are being targeted, the plan allows for highly focused research on the development of an integrated process that can handle the specific needs of softwoods.

The need for a separate activity stems from the compositional differences between softwoods and hardwoods, as well as differences in detoxification and hydrolysis needs as discussed in Section 4.1.1.

The following sections discuss in more detail each of the main activities outlined in the plan.

6.1 How to Read the Gantt Charts

The main Gantt chart for the baseline plan has been color coded to distinguish major areas of the program. Figure 8 shows how these have been color-coded. Linkages between and among various tasks are shown in several different ways. Arrows are drawn connecting one task to all of its successors.

Because of the size and complexity of the plan, it is not always easy to trace these lines. Therefore, linkages are also shown by listing the predecessor relationships that exist for each task in the text to the right of each Gantt bar. These linkages are written in a short hand next to the Gantt bar for a given (current) task that is explained below:

- [Task ID]. *This simply means that the listed task ID is a predecessor to the task. The task listed must be finished before the task on the current line can be started (a conventional Finish-to-start relationship). There can multiple predecessors listed*
- [Task ID]FS + {x}w. *The current task cannot start until "x" number of weeks after the finish, where "x" is defined as the lag time between the tasks when it has a positive value and it is defined as a lead time when it is negative. For lead times, this means that the current task can start "x" number of weeks before the finish of the predecessor task.*
- [Task ID]SS. *This means that the current task and the listed predecessor task must both start at the same time. Like a task with a finish-to-start relationship, a start-to-start relationship may have lag or lead times associated with it.*
- [Task ID}FF. *This means that the current task and the listed task must both finish at the same time.* Tasks with finish-to-finish relationships may also have lead and lag times associated with them.
- WBS. *The tasks in the plan have been assigned a WBS number or "Work Breakdown Structure" number. These numbers are written as aa.bb.cc.dd. In this format, "bb" is a sublevel activity of "aa" and "cc" is a sublevel activity of "bb", and so on.*

Finally, the Gantt chart includes some notes written across the tops of the Gantt bars. These notes usually provide some information about assumptions for costs or resource requirements. If there are subcontract costs associated with an activity, these notes will indicate what information we have about the subcontract cost and the nature of the subcontractors or partners doing the work. Likewise, capital or other direct costs are highlighted in these notes if they have been included in the fixed costs.

Important editorial note: Headings marked with an asterisk correspond to specific activities listed in the Gantt chart. Because of constantly changing aspects to the plan, activity ID numbers have not been provided in the text. While this makes it more difficult to track the text with the Gantt chart, the reader should be able to follow fairly easily between the text and the Gantt chart

6.2 Commercially Demonstrate Waste Biomass to Ethanol Technology

This section of the plan addresses several important elements of technology deployment:

- Identification and selection of partners
- Business plan development
- Pilot scale demonstration on specific partner-determined feedstocks

- Demonstration plant design, construction and start-up.

The elements of the deployment plan are taken from the plans for the Partnership Development Team. We have rigorously integrated the technology development and partnership development plans to produce a meaningful and comprehensive multi-year technical plan. Careful attention to timing between the needs of partners and the timeline for establishment of viable process technologies has caused a shift in the final date for successful start-up of the first waste biomass-to-ethanol facility. Start-up, in this current version of the plan, is not done until the year 2001. We could have looked for places to "crash" the critical path; but chose not to do this until the plan is fully resource loaded.

One thing that we discovered immediately is that the technology development efforts do not correspond cleanly to our timing for the two near term and mid term targets. As a consequence, there is at least one roll out of technology improvements which occurs between our near term and mid term goals. We have assumed that such technology roll outs can be done with industry partners involved in commercialization of the near term waste biomass to ethanol applications. Likewise, any such improvements are available to technology developers involved in our mid term target for switchgrass-derived ethanol. Explicit activities involved in transfer of incremental technology improvements are not shown in the plan.

6.2.1 Identify New Market Opportunities and Partners for Preliminary Feasibility Studies

As indicated earlier in this report, four key opportunities for near term deployment have been identified. They include:

- The utilization of softwood from western states removed from forests to reduce fire hazard and improve forest health
- The utilization of grain processing waste to produce ethanol
- Hardwood sawdust from milling operations
- And herbaceous crops produced on CRP farm land

The rationale for selection of these market opportunities is provided in more detail in the Biofuels Program Partnership Development Plan being developed in parallel with this multi-year technical plan.

Hardwood saw dust opportunities originally pursued several years ago with South Point Ethanol were discontinued after closure of their business. The Partnership Development Team will be re-examining this opportunity, along with other potential waste materials. These include bagasse, pulp and paper wastes, food processing wastes and agricultural residues.

6.2.2 Preliminary Feasibility Studies

This activity is broken down into existing and new partnerships. A series of feasibility studies are already planned for softwood market opportunities. Some of these studies are already underway. Other partnerships being established involve the use of CRP land. Finally, there are a series of partnerships that focus on more specific technical aspects of bioethanol technology, and not just market opportunities. These include engineering studies, life cycle analysis and collaboration on commercial cellulase production.

New partner-based preliminary feasibility studies for some of the additional opportunities outlined in the previous section will also be conducted.

When all of these studies have been completed, a decision will be made regarding which of these partnerships warrant a more detailed feasibility study. This decision point is the first major screening of opportunities.

6.2.3 Final Feasibility Studies

The final outcome of the feasibility studies will be a decision to commit the program to specific partnerships through which the first demonstration plant for bioethanol from waste biomass will be realized. This is a critical decision point for the program. This decision must be made in late 1997 or early 1998. Even with this aggressive schedule, we will not see a bioethanol facility on line before the year 2001. This makes clear the sense of urgency that underlies our near term deployment target.

6.2.4 Business Plans

Our partners will be the main driving force in the development of business plans for the demonstration plant. These plans will be concerned with specifics of siting the new ethanol facility as well as with questions of feedstocks to be used. During this phase of business planning, we assume that pilot scale studies will begin. These studies may occur at the Alternative Fuels Users Facility or at other locations, depending on the needs and resources of the partner. As indicated previously, it is important that pilot scale testing be done in the context of the partner's specific business plan.

There is an important linkage made at this point in the plan between our core technology development efforts and the commercial deployment efforts. Availability of a pilot plant with detoxification capability is assumed to be in place before the partner's pilot scale testing can be done. In addition, a bench-scale integrated technology based on our core technology plan is also assumed to be available at this point. Neither of these conditions are absolutely necessary. A partner with his own technology and/or pilot scale testing capability could proceed at this point without NREL's technology and facilities.

Because we do not have control or knowledge of capabilities outside our own efforts, we have chosen to plan deployment around what we know today for completion of an integrated process within the Biofuels Program. This is conservative in the sense that partners such as SWAN and Arkenol may be ready for pilot testing. As indicated in the complete Gantt chart, the decision to link our core technology plan with the deployment plan causes a delay of several months in the start of pilot scale testing.

Finally, our partnership with Amoco has already been through pilot scale testing. Under phase 4 of the Amoco partnership, demonstration of a corn fiber-based plant could occur as soon as mid 1998.

Pilot scale test results will be used to re-evaluate the economics of the process and to re-assess the business plan. With revised business plans in place, a go/no go decision by the partner will determine if the project will move into the final phase of design, construction and operation of a demonstration plant.

6.2.5 Demonstration Plants

Establishment of a demonstration facility involves all aspects of building a manufacturing plant from financing to final start-up. An approximately one year period is allowed for detailed design. Permitting and construction take place in parallel paths about three months into the detailed design phase. Finally, start-up of the facility is assumed to take six months.

The end of the start-up phase for our first waste biomass to ethanol facility occurs in the second quarter of the year 2001.

6.3 Develop Switchgrass Partnerships for Ethanol Production

Oak Ridge National Laboratory will focus a significant portion of their feedstock development program on developing switchgrass as a cost-effective and environmentally beneficial crop which can be dedicated to supplying an ethanol conversion facility by the 2005 time frame. The integrated plan relies on switchgrass to be the primary feedstock for a newly developed conversion process. The plan that follows describes activities of the feedstock development program that will increase the probability that switchgrass producers will be interested and ready to participate in commercially demonstrating switchgrass to ethanol technology by 2005.

6.3.1 Identify potential locations for switchgrass supplies at $42/dry ton delivered*

Switchgrass prices will vary by location. Identification of locations that have the potential for producing supplies at $42/dry ton (or less) is an important first step in determining how to most efficiently use federal research dollars for making rapid progress toward meeting DOE s Ethanol Program Goals.

The analysis effort will identify, by mid- 1998, at least four desirable locations for a cost-shared demonstration of ethanol production from switchgrass. This information will be used to focus both ORNL's and NREL's outreach efforts to stimulate producer and developer interest in conducting feasibility studies and in business plan development. Identification of desirable locations must include consideration of project development partnership opportunities and political and social support for switchgrass-based ethanol as well as the biological capabilities and land values being modeled by Geographic Information System techniques. Information available by early 1997 will be factored into decisions on additional field-testing sites for switchgrass. Products from the analysis effort will include databases, maps and publications which will be made available on the Internet, through other electronic formats (disks and cd's), and through hard copy publications. These products will be made available to anyone interested in policy analysis and project development and will facilitate informed economic and ecological decisions relevant to the deployment of bioenergy projects. Outreach efforts will be made to ensure that these products get into the hands of state energy office and potential project developers.

6.3.2 Assist feasibility studies with integrated analysis products*

Several analysis products being developed by scientists at ORNL in collaboration with scientists at universities and other agencies will contribute significantly to credible feasibility studies and to recommending general areas for pursing feasibility studies. Products include the following: (1) the BIOCOST economic models which will be updated as new information becomes available, (2) maps showing potential crop cost ranges based on the linkage of BIOCOST analysis with geographic information on land types, land cost, and transportation systems, (3) national and regional price/ supply curves of potential supplies of biomass feedstocks including residues and crops, (4) reevaluated supply curves based on use of USDA commodity crop supply models with switchgrass and poplar modules, and (5) farmer risk evaluation models. These models and products will be continually updated as new information becomes available from scale-up studies that are planned for initiation over the next 2-3 years. These tools will be released in a timely manner with each new update to interested government and private sector groups for their use and evaluation.

6.3.3 Identify best location for first switchgrass-based ethanol conversion project*

If the scale-up research is successful, all four areas will have the capability of providing the supplies needed at the desired price for a switchgrass-based ethanol project. However, DOE will only need to demonstrate complete integrated technology at one location. Once the switchgrass conversion component of the technology is ready for handoff to the private sector, then serious efforts will be made to facilitate bringing together the partners needed to develop one or more integrated projects. The program will facilitate business plan development at all four scale-up sites and possibly other candidate sites during year 2003. This will prepare developers to respond quickly to a solicitation for proposals to be issued in the fall of 2003. The best project should be identified by early 2004. A major selection criterion will be the extent to which local farmers and project developers are willing to bear the cost and risk of putting together an integrated project.

6.3.4 Expand switchgrass supply system expertise & interest*

The number of locations where switchgrass is considered by producers to be a viable crop is limited at present. Step one involves getting the information developed on switchgrass over the past 5 years summarized and distributed to a wide range of public and private groups.

Step two in expanding switchgrass supply expertise involves getting more people interested and involved in switchgrass R&D in more locations. This effort began in 1996 with the initiation of the Biomass Power program s integrated biomass energy project in Chariton Valley, Iowa. ORNL staff assisted with feasibility studies for that project and now have an oversight and advisory role in the project. Expansion efforts will continue in 1997 existing university subcontracts come up for renewal. ORNL will refocus their work to include linkages with the private sector and/or USDA testing centers. The USDA project in Nebraska will also be expanding to include linkages with a switchgrass breeder in Wisconsin. Efforts to establish linkages with USDA Plant Materials Centers at several locations in the US will also be pursued in 1997. The primary cost to DOE in this phase is assumed to be the cost of travel and phone calls to facilitate formation of the collaborations. The long-term cost of maintenance of the scale-ups and the clonal testing trials is included under section 5.X.2 as part of the core switchgrass technology research.

Step three of expanding switchgrass expertise requires development of data on the market potential of switchgrass based ethanol. Realistic market potential assessments depend on obtaining realistic data on the economics of production. Accordingly, an agricultural economist will be a key component of the scale-up research and development team for both the large and small scale-up efforts. It is likely that some of the participants in the scale-ups will participate in the ethanol feasibility studies planned for 1999. Whether or not this is the case, the economic information will be available for those feasibility studies.

Expanding public interest in switchgrass-based ethanol requires developing and disseminating information on the environmental benefits and costs associated with producing switchgrass for ethanol. Such information will be a valuable input to the feasibility analysis scheduled for 1999. With current and anticipated funded levels, environmental data will be limited, however, some predictions will be possible based on linked economic and environmental models currently being developed. A significant milestone of the feedstock development program will be to summarize all available information from the scale-up trials in early 2000 and make it available to participants in the final feasibility studies.

Stimulation of producer interest in growing switchgrass by the year 2000 will require considerable investment in outreach activities in targeted areas. These outreach activities will be conducted collaboratively with staff from the National Renewable Energy Laboratory, with university and USDA researchers and extension personnel, and with members of various Resource Conservation Districts around the country. The outreach will include every format available including news broadcasts, field days, workshops, development of information brochures

6.4 Commercially Demonstrate Switchgrass to Ethanol Technology

The same basic steps shown for deployment of the waste to ethanol technology in the year 2000 are assumed for deployment of the mid-term (year 2005) technology. The difference is the incorporation of the steps relating to supplying a dedicated feedstock. Both the feedstock and conversion core technology development work have a significant impact on the timing and completeness of the feasibility studies and partnership selection. Analysis efforts being initiated in 1997 and 1998 will also be key inputs to the feasibility studies conducted in 1999 and the year 2000. The selection of the partners and locations for final feasibility studies in the year 2000 is a key milestone that will significantly affect how and where feedstock core technology and market development dollars are spent.

The use of switchgrass as the primary (or total) supply is a high-risk strategy because it requires the simultaneous development and successful implementation of new technology in both the agricultural and ethanol industries. Availability of switchgrass will depend on convincing farmers of the market opportunity and the potential for profitability. A successful result, however, would have a high payoff in terms of obtaining farm community support and participation in further development of a lignocellulosic ethanol industry in other parts of the country. The risk associated with a switchgrass only strategy is buffered by two ongoing activities: (1) NREL and ORNL are collaborating on conducting analysis to identify locations, amounts, and prices of alternate feedstocks such as agricultural and forestry residues, and (2) NREL and ORNL are collaborate with the forest products industry on research and development of woody crops for fiber and energy in expectation that partnerships could be developed to obtain a portion of the wood from plantations being established by the fiber industry.

6.4.1 Business Plan Development

A major element of the business plan development process will be the negotiation of legal arrangements between the project developers, feedstock suppliers, financiers, and conversion technology suppliers. The critical linkage between the feedstock and conversion technology development programs which will affect these negotiations is the process testing of switchgrass as a potential feedstock. The process tests will occur by or before 2002 in order to meet the deployment schedule outlined. Tests results showing that the conversion technology can be adapted to efficiently utilize switchgrass feedstocks will be necessary before final process design costs can be determined. Those costs along with feedstock supply cost estimates are critical to developing the final business plans with selected partners for a selected location.

6.4.2 Integrated Demonstration

An integrated demonstration of lignocellulosic to ethanol technology will include a linkage between the agricultural producers and the ethanol facility project developers and managers.

To bring the agricultural producers into the partnership in a timely manner, selection of partners and a location for the feedstock-supplied facility will be finalized by early in 2003 so that feedstock supply contracts and financing can be finalized before the fall of 2003 to allow site preparation and planting by spring of 2004. A spring 2004 planting is necessary to assure adequate feedstock supply by late 2005. The first harvest in late fall 2004 can be used for start-up trials that will occur during 2005. Commercial operation would not begin until November or December 2005 when the switchgrass crop should be at full production capacity.

The facility construction and operation schedule is also dependent on finalizing partnership selection by early 2003. The schedule allows minimal but sufficient time for completing facility design, permitting, construction and start-up tests. Final design of the conversion facility cannot be completed until a specific location is identified. Once location is identified and the overall plant design adapted to local conditions, then the permitting process can be initiated. The permitting process should include a NEPA review which includes the impacts of producing the crop as well as factors associated with the siting of the plant.

If the plant does not start commercial operation in late 2005, the business arrangement will likely have to include a mechanism for paying the farmers for the crop in any case. It will be possible to judge the success of stand establishment and potential supply well before the fall harvest so that alternative feedstock supplies can be acquired if necessary. Even if commercial deployment of the conversion technology is accomplished in 2005, and the first year switchgrass harvest provides an adequate supply, the full measure of success of the switchgrass production system will not be measurable at that time. The system will be adequately demonstrated when high-quality, low-cost supplies are shown to be consistently available as needed over a 3-5 year period.

6.5 Core Technology Development

6.5.1 Switchgrass Feedstock Production Technology*

Switchgrass has been selected as the primary feedstock for the year 2005 lignocellulose to ethanol demonstration because; 1) it is technically feasible to establish an adequate supply of dedicated switchgrass feedstock within 2 years, 2) it is suitable for much of the type of land that is currently in the CRP and set-aside land programs, 3) the GIS studies which are identifying economically feasible locations will have information on switchgrass locations first and, 4) the biological risk factors are relatively well understood and significant progress toward reducing those risk factors can be accomplished in a few selected locations in the short time period remaining before 2005. The plan that follows is a core technology development plan that will be needed to support a substantial and widespread industry as well as preparation for the first integrated switchgrass to ethanol demonstration.

*6.5.1.1 Support Switchgrass Crop Development Centers in at least 4 regions**

Switchgrass research and development needs to proceed simultaneously in four to five regions of the US in order to insure that the developing cellulosic ethanol industry will have adequate flexibility in choosing suitable locations. The five regions mentioned in the Gantt chart include the North Central region, the Northeastern region, the Northeast/Lake region, the South Central region, the Southeast region and the Mid-Atlantic region. At least one fully integrated crop development center is desirable for each region. The activities of different regions and crop development centers are lumped together in the Gantt chart if the timing of the activities is the same.

An integrated crop development center assures that screening, cultural optimization, breeding, environmental, and basic physiological research or molecular biology are conducted in an integrated manner. The result is that similar genetic materials are being evaluated in cultural optimization trials, environmental, and physiology studies and that data from all of the aspects of the research are exchanged and linked so that the whole production system can be optimized most efficiently. Since the range of expertise needed usually can not be found within a single institution, it has been the approach of ORNL to facilitate linkages among institutions to form a virtual crop development center within a region.

The groupings of projects that form crop development centers in each region consist of the following.

(1) The North Central region includes the joint USDA/ARS and DOE sponsored breeding and variety screening research at Lincoln, Nebraska, and the soil and water quality studies on switchgrass conducted by staff at the University of Minnesota and the USDA North Central Forest Experiment Station. A DOE cost-shared biomass power integrated demonstration project in Chariton Valley, Iowa will benefit from and contribute to development of switchgrass for ethanol in the region.

(2) The Northeast/Lake states will be served primarily by a new breeding and variety screening activity initiated in 1997 in Wisconsin. The Wisconsin project will link closely to the Lincoln, Nebraska project and may have satellite test sites at USDA Plant Materials centers in Michigan and New York. A switchgrass power production project in Wisconsin will contribute switchgrass economic information .

(3) The south central region includes a breeding project located at Oklahoma State University and a screening/cultural optimization project lead by Texas A&M. The Texas A&M project will include a limited scale-up effort.

(4) The southeastern region has a new breeding project started in 1996 located at a USDA/ARS research laboratory in Georgia, a variety screening/cultural optimization project lead by Auburn University staff since about 1991 and an environmental study at Alabama A&I.

(5) The mid-Atlantic region is served primarily by a variety screening/cultural optimization project lead by Virginia Polytechnic Institute and State University (VPI&SU) with test plots located in 4 states. Work on biotechnology , physiology, and advanced breeding techniques at the University of Tennessee and at Oak Ridge National Laboratory is linked to the VPI&SU project as well as projects in other regions.

Not all of the regions will have fully integrated crop development activities. Since near term opportunities seem to look better in the south and mid-Atlantic, the initial focus will be on the southern and mid-Atlantic centers. However, crop development in the north will not be ignored since a large segment of the current corn to ethanol industry exists in the north. The categories of activities included in the crop development center concept are explained in all of the following sections.

6.5.1.1.1 Identify best varieties and yield potential*

The first step in any crop development program is to assess the currently available material and to gain information on performance over a range of sites. Since the status of the work is different for the southern US (plus mid-Atlantic area) and the northern US, they are separated on the Gantt chart and in the following descriptions.

Screening for best varieties in the South and mid-Atlantic States is being performed by three projects with a total of 19 field sites. Six sites are in Texas, seven are in Alabama and six are spread out between VA, TN, KY, & WV. The trials are showing that yields of the best varieties are averaging 5-7 dry tons/acre/year over all sites after 4 years of growth. The best variety on the best sites are producing in the range of 9-12 dry tons/acre/year. The established variety trials have been in place five years , thus long enough to make definitive recommendations on suitable varieties for a limited range of site types. Those recommendations will be used to select varieties for establishment in larger scale trials anticipated to start in 1997. Variety screening needs to continue through 10 years at the original sites, and be expanded to a much larger number of sites in the region. Those groups and institutions with experience in establishing and maintaining switchgrass will be involved in expansion of variety trials, along with staff from new institutions such as USDA Plant Materials Centers. Contractors will be encouraged to establish some of the new variety trials in locations shown to high potential by the GIS studies.

Screening for best varieties and locations in the North central States has been limited to the efforts conducted by the collaborative effort with the Agricultural Research Service at Lincoln, Nebraska involving only 2 sites. Beginning in 1997, the Biomass Power program is funding efforts to screen available switchgrass varieties to determine suitability for the Chariton Valley project. The new screening efforts in the Chariton Valley will build on the prior switchgrass screening in Nebraska and Oklahoma State University, and will likely be coordinated with future Nebraska and Oklahoma screening. Limited screening will be expanded to several North central states.

6.5.1.1.2 Optimize culture to improve yields & benefit environment*

The cultural optimization activities are divided into two categories related to the status of the work. The work has proceeded further in the southern and mid-Atlantic states than in the northern states. Each paragraph below relates to activities under cultural optimization shown in the Gantt chart.

In the southern states, some cultural optimization work has been conducted in association with the variety screening trials. Results of the preliminary recommendations either has been or will soon be summarized in the form of "guidelines" that can be distributed widely to potential growers in the Southeast. Cultural optimization will continue with selected varieties and be enhanced to gain solid information on yield/response relationships. Yield/response data will be important for updating models predicting potential supplies, economics and environmental impacts of biomass systems. The expanded cultural optimization efforts will result in improved management guidelines by the year 2000. Those guidelines will be available to participants involved in conducting feasibility analysis for the demonstration switchgrass to ethanol facilities

The cultural optimization effort in the North central is on a somewhat similar time line as that in the south and mid-Atlantic states, but the amount of information available from the effort is considerably less. Whereas the south has information from several sites, the northern states have information from only one site in Nebraska for the 1997 milestone. By the year 2000 there could be some very good information based on up to 4000 acres from the Chariton Valley project in Iowa, but it will be preliminary in nature since much of the 4000 acres will have been planted only 1-2 years. Because ORNL is working collaboratively with the Chariton Valley project , whatever information is available will be used to assist in feasibility studies to be conducted in the year 2000 for an ethanol facility.

Some of the cultural optimization projects will go beyond yield/response relationships to investigate the physiological mechanisms controlling the responses. ORNL physiologists will be directly involved in those studies collaboratively with university staff. These mechanistic studies will evaluate alternative nutrient sources such as organic wastes and ashes as well as traditional nutrient management sources to determine any differences on crop performance or soil sustainability. The mechanistic studies will be tasked adding improvements to the guidelines for environmentally sound switchgrass cultural management by 2002. One of the desired results of the studies would be a model-based diagnosis of the effect of soils, climate, nutrient regimes and harvesting regimes on plant growth and survival and soil sustainability over the long-term.

Once the business partners are selected in the year 2000 for final feasibility studies of the switchgrass to ethanol facility, the feedstock program will shift a portion of research funds toward initiating culture studies within close proximity of the candidate site or sites. It is anticipated that this work will be heavily cost-shared by local champions of the potential projects, thus keeping the cost at a reasonable level. It is necessary to begin the culture adaptation studies in the year 2000 in order that a switchgrass stand can be planted with a high probability of success by 2004. The culture adaptation process would focus on establishment techniques, fertilizer levels and types and herbicide treatments - but would also include testing a number of varieties on the available soils.

6.5.1.1.3 Evaluate environmental effects of culture techniques at few sites*

In the south, a limited amount of environmental research is currently ongoing. These studies will be summarized in time to provide input to the feasibility studies conducted in 1999 and for policy analysis that may be conducted by other groups such as EPA. While additional environmental research on a variety of soil types would be desirable, no plans for independent environmental studies are shown in the Gantt chart at this time. Environmental research at the experimental level will be incorporated into the cultural optimization studies and environmental monitoring will be included in scale-up studies conducted in the south.

In the north, experimental scale studies of the water quality and soil quality effects of switchgrass and poplars have been initiated in Minnesota. Those studies will have sufficient information by the year 2001 to assist in improving cultural guidelines for the northern regions.

To be effective in promoting acceptance of switchgrass to ethanol technologies, ORNL staff are prepared to spend a substantial amount of time on educating the public about environmental issues. This will take the form of (1) conducting analysis, preparing guidelines and brochures and other educational materials about environmental issues and (2) organizing or giving presentations, seminars and workshops on environmental issues. Several people may be involved, but the effort allocated is equal to 1 full-time equivalent person for the feedstock program.

6.5.1.1.4 Improve yields through breeding and testing

Developing new varieties through breeding is a long-term effort even for switchgrass. The typical approach to switchgrass breeding involves 2-3 years of breeding various combinations of seed sources. The resultant seeds are out planted each year and the populations are compared for 2-3 years in common garden trials near the breeding center to identify those plant populations with superior characteristics. Once identified, seeds are collected and testing is expanded to a wider range of locations and environmental conditions. Only after proving that superior characteristics are maintained over a range of conditions for 4-5 years, can a new variety be identified and released to seed companies. This often requires 10 years. Different parts of the country are in somewhat different stages with respect to switchgrass breeding.

Fully tested new materials for the southeast will not be available until about 2006. The USDA/ARS unit at the University of Georgia will be a cost-sharing partner in the breeding from the beginning and at some point it is anticipated that USDA will assume total responsibility for the breeding effort.

Oklahoma State University will likely provide new commercial varieties for the south central region by 2001. This is contingent on funds being available for adequate field testing at several sites in the region. Connections are currently being established with 2-3 USDA/NRCS Plant Materials testing centers for evaluation and distribution of advanced switchgrass varieties.

The USDA and DOE collaborative breeding effort in Lincoln has already released one new variety. With the phase two shown as starting in 1997, the project will be incorporating new information on the physiology of switchgrass into it s breeding strategy. With adequate funds for regional testing, it is possible that new switchgrass varieties could be available for commercial demonstration by 2003 for a project located in Nebraska, Iowa, or Southern Minnesota.

A new breeding/screening effort will be initiated in Wisconsin in 1997 as an extension of the Lincoln, Nebraska breeding effort. New germplasm will be collected for breeding purposes and the Nebraska varieties will be tested. New varieties for Wisconsin and other Lake States would not be anticipated until at least 2007 but the best varieties among currently available materials would be identified much sooner.

6.5.1.1.5 Develop physiology/ biotechnology information*

Switchgrass growth physiology research will continue through at least 1999 at ORNL, simultaneous to the regional breeding efforts. The ORNL physiology research is linked closely to all four breeding efforts. Biotechnology techniques being developed by the University of Tennessee (UT) are anticipated to be useful for improving the rate of breeding improvements as well as gaining more control over progeny characteristics. UT will use genetic mapping to document variety differences, breeding progress and fidelity of seed sources. Although the UT effort will not be complete until about 2001, it is anticipated that interim results will be adopted by breeding projects much sooner.

6.5.1.1.6 Assure sustainable yields by addressing pathogen & pest issues*

Agricultural experience suggests that pests usually emerge as crops become more domesticated for specific end-uses. Insurance against future yield reductions will be gained by identifying the most likely pathogens and pests and beginning the process of developing environmentally sound control mechanisms now. The preferred control mechanism will be to incorporate selection for resistance to such pests into the genetic improvement programs. To complement selection for resistance, strategies for integrated pest management will be simultaneously developed.

6.5.1.2 Reduce risks & expand expertise through scale-up research*

The existence of successfully operating scale-ups will be absolutely necessary to building the partnerships needed to successfully deploy switchgrass to ethanol technology by year 2005. These sites will build the type of expertise needed for the feedstock supply side of the partnerships and provide the information needed to reduce risks. The sites will also be important for showcasing to policy makers the value of developing an energy production system that involves farmers and may assist in the transition to an agricultural sector that is less dependent on government assistance.

6.5.1.2.1 Expand number and scale of switchgrass field R&D projects*

This activity follows from scale-up activities initiated under section 5.2.3 and covers the costs and labor associated with long-term maintenance of the scale-ups and research on cultural management associated with the scale-up plantings. The participants will include farmers, university and USDA researchers and extension agents as well as local Resource Conservation and development district staff. The scale-up in the Chariton Valley of Iowa is being funded by the Biomass Power Program with ORNL staff serving in an advisory and oversight role for the project. Scale-ups in the south central and southeast regions will represent a second phase of the ongoing variety and cultural testing trials at Auburn University and Texas A&I funded through the Biofuels Program. A new planting in one or more alternate regions will be initiated in 1998 if suitable expertise can identified in the areas where cellulosic ethanol projects are under consideration. Possibilities may exist in several states, thus the opportunities would be prioritized with DOE Biofuels Program input depending on funding levels available.

It is anticipated that the commercial scale-up to be associated with the year 2005 switchgrass to ethanol plant will be an outgrowth of one of the research scale-ups that will be initiated between 1997 and 1999. If the commercial location is not located near one of those planned research scale-ups, then research on switchgrass research activities could be initiated near the facility and scaled-up as research results and commercial plans dictate.

6.5.1.2.2 Improve Engineering of Switchgrass Harvest, Handling & Storage operations*

Switchgrass engineering research will not need to be repeated in every region, but will be needed at more than one location to insure that regional differences in farming equipment size, field sizes, transportation constraints, and rainfall patterns are taken into consideration. This work is shown as ending in 2001 only 3 years after initiation, just in time to contribute to final negotiations of license agreements and performance guarantees for the ethanol conversion facility planned for the year 2005.

6.5.1.2.3 Perform economic and risk studies with scale-up data*

Many of the crop management recommendations developed thus far have been based on small plots of less than 1 acre located at agricultural research stations where the sites are well-maintained and site variation is small. System cost validation and environmental effects monitoring can only occur on larger scale sites. Pathogens and disease may not become evident until larger plantings are established in several locations. Good estimates of feedstock production cost must include an understanding of yield variation as a function of microsite differences and the variation in harvest and handling efficiencies under operational conditions. For predictive purposes, it is important to learn something about learning curve times and about how year to year variations in weather patterns affect harvest and handling efficiencies and costs. The Gantt chart shows that economic and risk studies would be performed for only the two years prior to the establishment of switchgrass in 2004 for the commercial switchgrass to ethanol demonstration in late 2005. This amount of effort would be the minimum needed to prepare for the first commercial scale-up but follow up studies under the actual commercial conditions are likely to be proposed in order to improve performance for future commercial ventures.

6.5.1.2.4 Monitor and document environmental effects*

Certain types of environmental effects such as the effect of switchgrass plantings on regional biodiversity and wildlife habitat can only be understood with large-scale or commercial plantings. Effects on soil and water quality can be predicted based on small plot studies, but monitoring of these types of effects on a broader scale will be necessary to persuade the public of actual benefits. If environmental benefits are to have any chance of contributing monetary benefit to commercial projects, development of credible monitoring techniques will become very important. Environmental guidelines will result from this work and will be very important for communicating the most environmentally beneficial methods of producing switchgrass.

6.5.1.2.5 Establish switchgrass quality variation for ethanol conversion*

Just as coal varies from location to location, switchgrass will also vary. The program will determine the extent of that variation and incorporate that information into optimization of the technology for switchgrass feedstocks. The evaluation of feedstock quality variation will increase the efficiency of optimizing the conversion processes for switchgrass and reduce the risk of feedstock related processing problems. Knowledge of the effects of various management, harvesting and storage options on feedstock quality will also help in finalizing a switchgrass production and supply strategy that will be most cost-effective for the system as a whole. Feedstock characteristics to be sampled for variation will be developed through discussions with the process developers at NREL and other research organizations.

6.5.2 Softwood Technology Development*

A three part plan is proposed to develop the technology package needed to commercialize the conversion of softwoods and softwood residues to ethanol. The first activity is to screen the available technologies to determine those that are most likely to be included in a technology package for the conversion of softwoods in the near term. This activity has been completed by the Partnership Development Team (PDT). Nine technologies and five process configurations were identified as the best options for bringing the technology rapidly to commercialization.

The next step in the technology development plan is to gather and analyze information about the nine technologies and then model the five process options. The information gathering will be done quite rapidly by literature searches and phone calls and meetings with the technology inventors, holders and developers. Through these activities we hope to gather enough information to adequately model the process options. The PDT will perform the process modeling. Technology and data gaps will become very apparent at this stage of the development plan.

The third and final step in the softwood technology development plan will address filling the technology and data gaps. We envision that this will be done through subcontracts and in-house research utilizing bench-scale, as well as the PDU at NREL. NREL will not attempt to develop technology, know-how, or equipment that exists elsewhere. We will instead tap into the existing knowledge through subcontracts or CRADAs to develop a complete softwood technology package. Schedule and resource information presented herein are our best estimates for this activity at this time. A more detailed plan will be developed when the analysis of technologies and process option is completed.

Based on our preliminary literature survey of softwood conversion technologies, key data required for adequate process modeling are missing in the following areas:

- Feedstock:

Little or no data is available on the conversion of softwood species of interest (i.e., Douglas Fir, Ponderosa Pine and true fir). Most published data on pretreatment and enzymatic hydrolysis are for spruce, *Radiata* Pine and white pine. The conversion of softwood forestry residue also poses questions on whether whole tree chips are acceptable or most of the needles and bark need to be separated from the wood.

- Dilute acid pretreatment:

There are a few publications on acid pretreatment of softwood. Saddler and Clark claimed almost complete enzymatic hydrolysis of SO_2-steam pretreated spruce and *Radiata* Pine. H.E. Grethlein reported 65% enzymatic hydrolysis of glucan following dilute sulfuric acid pretreatment of white pine. C.J. Biermann reported essentially complete enzymatic hydrolysis of cellulose in acid chlorite treated pine and cedar shavings. It appears that there are technology gaps in dilute sulfuric acid pretreatment.

- Fermentation:

None of the research on softwood pretreatment mentioned above included ethanol fermentation. Because softwood contains high content of extractives, it is reasonable to assume that dilute acid pretreatment would generate inhibitors to fermenting microorganisms. This may lead to further needs for adaptation of fermenting microorganism to the inhibitors or detoxification work.

- Enzyme production:

Enzyme production on site is key to an enzyme based softwood-to-ethanol plant. Engineering and cost data are required to complete the process technology package.

- Total hydrolysis of cellulose and hemicellulose:

  <u>Dilute acid hydrolysis</u>. The Pretreatment Team is developing a flow-through dilute acid hydrolysis process. A lot of data have been generated on hardwood but not on softwood.

  <u>Concentrated acid hydrolysis.</u> Very little published data on concentrated acid hydrolysis of softwood is available in the literature.

  <u>Acid catalyzed organosolv saccharification (ACOS)</u> Paszner (6) claimed that his ACOS process completely dissolve lignocellulosic biomass (softwood, hardwood, herbaceous, etc.) and the sugars are fermentable to ethanol following some type of

detoxification process. This work has been performed in lab scale equipment and the fermentation yields have not been verified.

Solid residue utilization and waste water treatment: Most studies on biomass ethanol process technology lack waste disposal data and often underestimate the cost of waste treatment. Data on dewatering and combustion characteristics of solid residue (after fermentation), BOD and toxicity of waste water are required for plant design and cost estimate.

- Equipment:

  Operation of the NREL PDU has revealed the needs for better selection of equipment, such as solid/liquid separation.

6.5.3 Process Integration for Core Technology*

The goal of the team performing this activity is to utilize all available information and technology to develop integrated bioethanol process technology that supports the commercialization of bioethanol and the reduction of bioethanol manufacturing cost. This support may be provided directly to external entities via publications or other means, or through partnerships with NREL for the development of process technology. The information generated will be a series of deliverables on the function of one or more unit operations making up part of an integrated process. It will culminate in the availability of an integrated process including pretreatment, detoxification, cellulase production, cellulose hydrolysis and fermentation of sugars to ethanol which meets the year 2000 performance goal. The team will also work to provide the facilities required for an industrial partner to complete demonstration of the process in a timely fashion to meet the goals for commercializing the technology.

Many reports exist on the best pretreatment, or best fermentation technology but far fewer tell of integrated process technology. NREL's strategy to be a major source of new process technology for bioethanol is the following:

1. Develop a bioethanol process that is cost competitive in today's market on a low value feedstock
2. Develop process knowledge on the many different feedstocks, pretreatment technologies, microorganisms and other innovations that fall within the technology area that NREL is developing, and
3. Integrate new unit operations or process technology into the best existing process to develop lower projected manufacturing costs for bioethanol.

Because of the large number of options for process technology in the areas of feedstock, fermentative microorganism, pretreatment, etc. the details of the research and development we are pursuing requires some explanation. Several key process variables have been "fixed" as initial development of integrated process technology is conducted to simplify developmental work and to insure that all important process variables are investigated.

Two examples of "fixed" variables are the feedstock and the microorganism. For the initial development work, the feedstock we are working with is yellow poplar hardwood sawdust. The current choice of microorganism for fermentation is the recombinant, glucose and xylose fermenting *Zymomonas mobilis*.

The process deliverables developed will be passed on to commercial development with NREL's industrial partners on a continuous basis. An advantage of this is that all NREL developments will be equally available to all industrial partners.

In the past, we have allowed frequent changes in the choice of these key variables, often to meet the needs of industrial partners. While this satisfied the industrial partners, it did not allow NREL to complete the development of integrated process technology which could be shared with all industrial partners. The core technology process development activity has the commercial development partners of NREL as its customers.

Hardwood sawdust is an excellent model feedstock for the process development activity. It is very representative of potential energy crops in terms of its hemicellulose and cellulose content and it is available year round minimizing storage issues. For these reasons and those stated in preceding paragraphs, we consider the process development work being done by this team as essential to the deployment of DOE's core technology for bioethanol.

While the process development effort on hardwood sawdust serves as a baseline for demonstrating an integrated process, we recognize the need to know the sensitivity of the processes under development to various feedstocks, microorganisms and pretreatment processes. However, initially it is important to have data and knowledge developed on the large number of assumed performance parameters contained in the technoeconomic model. Much of this data and knowledge does not change with a change in feedstock or microorganism (e.g. cellulase production engineering or detoxification to remove acetic acid and related compounds). This information can then be applied to the needs of many different industrial partners working with NREL.

In order to utilize resources most effectively and achieve goals in the shortest possible time, an approach to prioritize possible process improvement projects is needed. The approach used to develop a cost effective process technology is as follows:

1. Key process variables are "fixed" and a process meeting minimal performance (not necessarily

cost effective) targets is developed,

2. A technoeconomic model is used to evaluate the projected ethanol cost for the minimal process technology,
3. Improvements in process performance are proposed and the process cost reduction to be achieved is estimated,
4. The required resources for a given project are estimated as well as the risk of failure,
5. The possible process enhancements are prioritized on the basis of 3) and 4) and the highest ranked are pursued, and
6. New improvement ideas are ranked on a continual basis for inclusion into the process developmental work.

In addition to the above approach the process development team will continually seek to reduce the number of non-supported assumptions in the technoeconomic model. Process assumptions such as the recycling of water through the process and the Btu value of the spent solids from distillation will be investigated to provide confirmed values. Process equipment assumptions such as materials of construction will be confirmed where possible by carefully designed research. As a result research objectives will come from the rigorous approach outlined above and the need to confirm as many model assumptions as possible. As the model assumptions are all confirmed then the approach outlined above will be used exclusively.

Additionally, as progress occurs, more process sensitivity analysis will occur. Examples include the testing of different feedstocks or different microorganisms than those chosen initially. Choices made will be dependent on commercial demands and availability of alternate technology.

As new technology options become available, the process development team will work to integrate the new technology into the process with the objective of minimizing the bioethanol production cost. New options for the process are already in the pipeline. These include:

1. Countercurrent prehydrolysis,
2. A new ethanol producing microorganism such as *Lactobacillus*
3. A new cellulase production technology
4. New cellulase enzyme systems, and
5. New options for lignin utilization.

The initial approach will be to establish a working integrated process with the new piece of technology as outlined above. Then sensitivity analysis will be used to determine the ethanol cost reduction for various improvement possibilities. This information will be combined with a technical and risk evaluation of the improvement to rank all possibilities. The research will be executed based on the priorities established to develop a more cost effective process technology. If the improved piece of technology cannot be successfully integrated, then it will be returned to the developing team with input on what needs to be changed to make it effective. This approach applies to technology developed at NREL and other organizations.

The above provides a complete overview of the approach and strategy of the integration and process development team. We are confident that the approach and strategy outlined will enable us to achieve the year 2000 technology objectives as well as the year 2005 technology objectives.

The following sections provide more information on the specific tasks found in the MYTP Gantt chart.

*6.5.3.1 Provide commercial development facility capabilities to support industrial partners.**

There are two parts to this goal:

1. To develop new capabilities to be utilized by industrial partners, and
2. To add capabilities to existing facilities that will better allow the facility to meet industrial partners needs in a timely fashion.

Over the next year, two projects fall into meeting this goal. The first is to bring the mini-pilot system on line and use it for high solids SSCF development work. The second is to add continuous liquid-solid separations, overliming and ion exchange equipment to the PDU to allow continuous conditioning of pretreated materials, if needed, prior to SSCF.

Projects in this category will arise out of the discoveries of the process development team or in equipment setups required to prove assumptions contained in the technoeconomic model. Commercial development will occur faster and industrial partner satisfaction will be higher if the facility needs identified are acted on prior to the actual need. These types of capability additions often require a year or more to implement. We expect a continuing stream of these types of facility capability enhancements in future years.

6.5.3.1.1 Demonstrate an integrated process for ethanol from cellulose in a mini-pilot plant system.*

There is a capability enhancement goal and two research goals imbedded in this activity. The three goals are:

1. To bring the mini-pilot biochemical conversion (SSCF) unit on-line for industrial partner and core technology use,
2. To demonstrate the integrated process qualifier technology at a scale large enough to close all material balances, and
3. To bring the mini-pilot system to complete readiness for future work on continuous SSCF's at higher solids loading.

The mini-pilot system allows integrated testing utilizing the Sunds pretreatment reactor, a centrifuge for liquid-solid separation, a column for ion exchange detoxification, a tank with pH control for overliming, a 50 or 100 liter SSCF feed tank, and several 15 liter biochemical reactors (fermenters) configured for batch or continuous fermentation. The work will focus on demonstrating the process qualifier technology which has been performed at the bench scale already.

6.5.3.1.1.1 Establish complete integrated process flow diagram and equipment to be utilized.

The mini-pilot system will be composed of pretreatment and hydrolysate conditioning performed utilizing pilot plant equipment, and the integrated scale biochemical conversion unit. Since the detoxification process has not been performed at larger than bench scale previously, careful planning of the required equipment for conducting this activity is required. The flow diagram will be developed with utilizing existing equipment and meeting required process conditions as the constraints.

6.5.3.1.1.2 Prove that aseptic conditions can be established and maintained in the biochemical conversion unit.

This testing of the biochemical conversion unit is required to insure it performs as the equipment was designed. The ability to establish asepsis in the fermentors and RACE's is required.

6.5.3.1.1.3 Obtain BL1-LS status for the integrated biochemical conversion unit utilizing the NREL recombinant Zymomonas strain.

Design a plan meeting the NREL's Institutional Biosafety Committee (IBC) approval for obtaining BL1-LS operating status. Collect the required data and document procedures and results in a report to the IBC. Answer questions of IBC and obtain approval for BL1-LS operation.

6.5.3.1.1.4 Design, procure and test ion exchange equipment for hydrolysate conditioning.

The objective of this activity is to produce intermediate quantities (50 to 100 liters) of conditioned hydrolysate for use in bench and mini-pilot experiments. Testing will also confirm engineering parameters prior to installation of this capability at the full pilot plant scale. Capabilities for producing intermediate quantities of pretreated material separated into hydrolysate and pretreated solids already exist. To utilize the mini-pilot system and speed bench scale research, a store of reproducible, conditioned hydrolysate and pretreated solids is needed. The hydrolysate is to be processed by the ion exchange/ overliming process with the solids washed with conditioned hydrolysate for conditioning of the solids. The equipment is not intended to process large quantities of material for use in the 9000 liter fermenters

6.5.3.1.1.5 Ready Sunds reactor to produce pretreated sawdust for integrated demonstration.

Repair and maintenance of the Sunds reactor and the feedstock handling system are required prior to utilizing the Sunds reactor. The data acquisition and control system must be checked to insure all safety interlocks are functioning also.

6.5.3.1.1.6 Run process qualifier technology demonstration in mini-pilot system.

An experiment to reproduce the process qualifier technology will be run in the mini-pilot system. Detailed material balances will be collected and continuous culture experiments may also be conducted. Pretreated and detoxified biomass will be charged to the biochemical conversion vessels. Enzymes and microorganisms will be added to the biomass in the same quantities as previously done at the bench scale.

6.5.3.1.2 Mini-pilot biochemical conversion unit available for commercial development.

This represents a milestone for completion of the work in MYTP Activity 4.5.1.1.1. This will be documented in the form of a milestone report on the demonstration of the process qualifier technology and the related activities.

6.5.3.1.3 Design full pilot scale detoxification equipment.

The objective is to design a hydrolysate conditioning system that is capable of continuously serving the 9000 liter fermenters and is capable of maintaining asepsis of the pretreated materials as established in the pretreatment process. The ion exchange/overliming process is the process to be utilized. The system will include equipment to conduct solid-liquid separations required for the ion exchange/overliming process.

6.5.3.1.4 Install full pilot scale detoxification equipment.

Once a satisfactory design has been achieved, the equipment must be procured and installed in the pilot plant. Data acquisition and control strategy must be determined and connections made for its implementation.

6.5.3.1.5 Test and modify full pilot scale detoxification equipment.

After substantial mechanical completion (including control and data acquisition links) the equipment must be tested and verified to perform as designed. If performance is not satisfactory, then modifications and additional testing will be done.

6.5.3.1.6 Detoxification process equipment available for pilot scale commercial development.

This is a milestone marking the readiness of the detoxification equipment for commercial development. The equipment must meet the constraints of continuous operation, successful detoxification performance and maintenance of process stream asepsis to complete the milestone.

6.5.3.1.7 Design SSCF system for pilot plant demonstration based on experimental results available.

The objective of this activity is to determine if current pilot plant capabilities can be used to successfully demonstrate the SSCF performance required for full pilot scale demonstration. If it does not, then additional required equipment must be designed and added to the system to provide equipment capable of fulfilling all demonstration objectives.

6.5.3.1.8 Evaluate "spent solids" for combustion value.

Small quantities of "spent solids" (the solid fraction after distillation) will be evaluated by combustion testing experts for their Btu value. They will also be evaluated for suitability for large scale combustion to the fullest extent possible with small quantities of materials. Requirements for a more definitive combustion test to be fulfilled by a full scale pilot operation will be determined.

6.5.3.1.9 Investigate the impacts of gypsum on the bioethanol process prior to pilot plant testing.

The objective of this activity is to determine if the presence of gypsum in process streams to distillation or to the biomass combustion chamber will add significant costs to the bioethanol process. Distillation experiments and the combustion tests with experts in these areas will be done for due diligence at the smallest possible scale. Pilot scale tests will be designed if the results are inconclusive.

6.5.3.2 Provide integrated process technology for commercial development meeting the cost target of $1.13 per gallon ethanol (year 2000 technology goal).*

The objective of this summary activity is to complete the development of integrated process technology that meets the MYTP year 2000 performance goal technically and economically. The activity includes work on pretreatment, hydrolysate detoxification, cellulase enzyme production, cellulose hydrolysis and fermentation of sugars to ethanol. The research and development required is largely bench scale work although some pilot and mini-pilot scale work is required in the engineering sensitive areas and to verify actual equipment performance.

The summary roll-up includes two major subactivities:

1. The development of cellulase enzyme production utilizing hydrolysate and pretreated solids, and
2. The development of pretreatment, detoxification and SSCF into an integrated process.

These two activities both have the constraint that performance must meet the MYTP year 2000 goal.

The activity is finished with the availability of a complete process information useable by an industrial partner in a commercial development activity. Although the industrial partner may be interested in a feedstock different from the hardwood sawdust, work included in the process development will allow a quick and predictable transfer of information to support commercial development of the chosen feedstock.

6.5.3.2.1 Develop cellulase enzyme production technology utilizing hydrolysate and pretreated solids.

The objective of this summary activity is to establish cellulase enzyme production utilizing hydrolysate and pretreated solids that meets the year 2000 performance goal.

6.5.3.2.1.1 Establish cellulase production on hydrolysate and pretreated solids.

The objective of this activity is to establish cellulase enzyme production on hydrolysate and pretreated solids utilizing a selected strain of the *Trichoderma reesei* microorganism. Key performance parameters including the cellulase volumetric productivity and the cellulase weight/weight yield on sugars consumed will be measured.

This information will be utilized to plan work aimed at improving performance to the year 2000 goal.

6.5.3.2.1.2 Improve cellulase production on hydrolysate and pretreated solids to meet the MYTP year 2000 performance goal.

The goal of this activity is to improve cellulase production performance to meet the year 2000 performance goal. Based on data collected in the previous activity experimental work will be planned to improve the cellulase production cost performance.

Improved technology related to induction of cellulase production by *T. reesei* is scheduled to be obtained from the Enzyme Technology Team in July 1997. This technology will be integrated into the process through bench scale work designed to show its improved efficacy and function.

This activity may include a factorially-designed experimental plan to evaluate the parameters with the largest impact on cellulase production cost. This could be followed by an investigation of the most important parameters to improve the cost effectiveness of cellulase enzyme production. Alternate process configurations will also be considered to reduce the cost of cellulase enzyme to meet the year 2000 goal.

This activity will not be executed if a cost effective cellulase production technology is verified to be available to NREL's industrial partners from other industrial concerns.

6.5.3.2.1.3 Cellulase enzyme production technology available for commercial development.

This milestone is complete when cellulase production technology has been confirmed to meet the year 2000 performance goals and is available for commercial development by NREL's industrial partners.

6.5.3.2.2 Improve the conversion of biomass to ethanol process to meet the year 2000 performance goal.

The goal of this summary activity is to raise the level performance of the integrated pretreatment, detoxification, cellulose hydrolysis and ethanol fermentation to meet the year 2000 goal.

The highest ranked projects we intend to pursue include raising hydrolysate concentration to 100 %, processing 20 % total solids in the SSF process, and adapting the recombinant *Zymomonas* to 100% technology as a baseline.

6.5.3.2.2.1 Produce pretreated and detoxified materials to meet team experimental needs.

Production of this material is essential to the cellulase production and the SSCF research to be conducted. Without consistent and readily available materials the research pace slows to a crawl, as much time is spent generating materials needed to conduct experimental work.

6.5.3.2.2.2 Improve pretreatment to increase cellulose digestibility and hemicellulose sugar yield.

The objective of this activity is to increase the digestibility of the pretreated solids and to increase the yield of xylose from the pretreatment process. All factors that show promise to affect the targeted variables will be evaluated in a factorially designed experiment. Important factors will be evaluated in additional experiments to determine conditions that significantly improve the targeted variables.

6.5.3.2.2.3 Develop Zymomonas strain adapted to 100% hydrolysate.

The objective of this activity is to eliminate the requirement for the ion exchange portion of the hydrolysate conditioning process. If successful the result will be a process that requires only overliming to produce hydrolysate that is fermentable. Continuous and batch culture techniques will be utilized to select for adapted strains.

6.5.3.2.2.4 Complete detoxification process development at the bench scale.

The detoxification process requires additional work in two areas. The first is testing the process's applicability to a wide variety of feedstocks. The second is collecting engineering data to determine the proper resin, operating conditions and scale-up parameters.

6.5.3.2.2.5 Provide data on applicability of detoxification to various feedstocks.

This activity is the milestone for work showing how the detoxification process works for a wide variety of feedstocks. The data should allow

NREL and industrial partners to estimate conversion efficiencies for various feedstocks prior to conducting experiments. The process development team believes that its results will transfer to a wide variety of feedstocks. The ethanol yield per dry ton of biomass will vary but the process used to maximize the ethanol yield will be very similar to that found for hardwood sawdust.

6.5.3.2.2.6 Investigate improved SSCF performance by consideration of alternate process configurations.

The objective of this activity is to generate demonstrated SSCF performance on 20% initial total solids and 100% hydrolysate. A factorially designed experiment will be used to evaluate the most important variables in achieving the desired SSCF performance. The most important variables will be investigated in SSCF conditions to improve the SSCF performance to the targeted values.

6.5.3.2.2.7 Investigate SSCF performance utilizing improved pretreatment, best detoxification, and best performing Zymomonas strain.

The objective of this activity is to investigate alternate cellulose hydrolysis and fermentation technologies compared to the simultaneous hydrolysis and fermentation. The alternates may only be slight variations of the SSCF now practiced but may offer overall process advantages. The study will conduct a minimal amount of experimental work and rely on process kinetic and economic models to predict the most favorable options.

Improved technology in the recombinant *Zymomonas* is scheduled to be available in September 1997. The new strains will be tested at the bench scale and process adjustments made to incorporate the improved performance characteristics of the new strain. The resulting improved fermentation strain will become part of the best integrated process technology.

6.5.3.2.2.8 Improved process technology ready for review and generation of new improvement projects.

The improved process technology from the previous task will be subjected to technoeconomic analysis. Improvement projects will be proposed, and these will be ranked by the team utilizing the teams project prioritization methodology. A project plan for the prioritized projects will be generated.

6.5.3.2.2.9 Prioritized improvement projects carried out.

The plan of prioritized improvement projects from the previous task will be executed and results compiled. The successful improvements will be tested in integrated format with the objective of meeting the year 2000 performance goal.

6.5.3.2.2.10 Integrated biomass to ethanol technology meeting year 2000 performance goal available for commercial development.

This milestone represents the completion of process development on pretreatment, detoxification, cellulose hydrolysis and fermentation to meet the year 2000 performance goal. The documented biomass to ethanol process technology is available for commercial development at the pilot scale by industrial partners.

6.5.3.2.3 Integrated process technology meeting year 2000 performance available for commercial development

This milestone represents the completion of process development to meet the year 2000 performance goals for an integrated bioethanol process. The integrated process includes cellulase production technology and biomass to ethanol conversion technology. The technical knowledge to meet the year 2000 performance objectives is now completely available to industrial partners for commercial development.

6.5.3.3 Test incremental improvements under integrated process conditions.

This is a summary of a number of specific improvements in pretreatment, enzymatic hydrolysis and fermentation technology that will need to be incorporated into existing process technology to develop a more cost-effective process technology. Continuing process improvements will also be made as part of these activities.

Three major sets of improved pieces of technology are anticipated. The first two will be applied to the appropriate waste feedstock for developmental purposes. The third improved process technology will be developed on switchgrass to meet the year 2005 performance goal.

6.5.3.4 First roll out of improvements in technology for near term waste feedstocks.*

This is a summary of process development and integration activities resulting from the availability of new pretreatment, cellulase production and fermentation technologies. It is anticipated that based on bench scale work the cellulase production and fermentation technologies will be incorporated into the existing process technology and made available to industrial partners by December 1999. The development and demonstration of a new integrated technology for waste feedstocks including the countercurrent pretreatment technology and the new cellulase and fermentation technologies will be worked on in this activity but not completed.

6.5.3.5 Test first generation countercurrent prehydrolysis technology in an integrated process*

This activity will take the new pretreatment counter-current technology and begin the process of developing an integrated technology based on this new pretreatment approach. It is anticipated that new lignin recovery technology will need to be developed. The hydrolysate fermentation will require some development although previous work should support this well.

*6.5.3.6 Test Phase I genetically engineered cellulase system in integrated process at the bench scale.**

New cellulase production technology will be integrated into the existing bioethanol conversion technology. Initial work on integrating this with the new counter-current pretreatment technology will also be done.

*6.5.3.7 Test improved Zymomonas strain in the integrated process at the bench scale.**

A new *Zymomonas* fermentation strain will be integrated into the existing bioethanol conversion technology. Initial work on integrating this with the new counter-current pretreatment technology will also be done.

*6.5.3.8 Documented improvements available for commercial development by industrial partners.**

Improvements in existing bioethanol conversion from new cellulase production and fermentation technologies will be documented and made available for commercial development by NREL industrial partners.

*6.5.3.9 Second roll out of improvements in technology for near term waste feedstocks**

This is a summary of process development and integration activities resulting from the availability of improved counter-current pretreatment, and fermentation technologies. The end result of this set of activities will be the availability of a new integrated process technology for waste feedstocks that includes the counter-current pretreatment and the latest cellulase production and fermentation technologies.

*6.5.3.10 Test second generation counter-current pretreatment**

The complete hydrolysis pretreatment will be the basis for a new process technology. Since the pretreatment process will be significantly different a new integrated process will need to be developed around it. While many parts of the process will be simplified by the new pretreatment technology lignin recovery and hydrolysate fermentation are expected to be the key challenges.

*6.5.3.11 Test "super" Zymomonas strain (robust) and/or Lactobacillus at the bench scale.**

New fermentation technology will be incorporated into the improved complete hydrolysis based process technology.

*6.5.3.12 Improved low-value feedstock technology available for commercial development by industry.**

This is a milestone for the availability of improved bioethanol process technology for low-value feedstocks incorporating the complete hydrolysis technology and a "super" *Zymomonas* strain and/or an ethanol producing *Lactobacillus*. The improved technology is available for commercial development by industrial clients.

*6.5.3.13 Develop integrated process technology for switchgrass conversion**

The bioethanol process technology for waste feedstocks will be adapted to switchgrass and improved to meet the process performance cost target.

6.5.3.14 Test improvements in fermentation strains at the bench scale.

Improved fermentation will be integrated into the complete hydrolysis process.

6.5.3.15 Test Phase II cellulase system at the bench scale.

Improved cellulase production systems will be integrated into the complete hydrolysis process.

*6.5.3.16 Integrate switchgrass to ethanol process at the smallest possible scale.**

The complete hydrolysis bioethanol process including the latest fermentation and cellulase technologies will be integrated at the smallest possible scale. This process technology will be improved to meet the year 2005 performance objectives.

*6.5.3.17 Switchgrass technology available for commercial development by industrial partners.**

This is a milestone for the availability of switchgrass conversion technology meeting the year 2005 performance objective. Commercial development with selected industrial partners can now be done.

6.5.4 Chemical Hydrolysis R&D*

Over the past two years, the focus of pretreatment technology development at NREL has been on dilute acid countercurrent reaction processes. The fundamental basis of this approach is rooted in the observation that the hydrolysis of xylan, the major hemicellulose component in most biomass feedstocks, is biphasic, with an "easy-to-remove" fraction that can be hydrolyzed under relatively mild conditions and a "hard-to-remove" fraction that requires more severe conditions. Kinetic modeling evaluation of various reaction configurations has revealed that a countercurrent approach with two stages of temperature varying by about 30 °C, is the best design for achieving high yields and recoveries of xylose sugars from xylan. In such a configuration, the dilute acid solution is moved from the high temperature stage to the low temperature stage countercurrently to the biomass particles, which are moved from the low temperature stage to the high temperature stage.

This countercurrent approach minimizes the residence time soluble xylose oligomers and monomers in the high temperature environment that is necessary for near-complete xylan hydrolysis, resulting in minimal levels of sugar degradation reaction products such as furfural.

The initial efforts of dilute acid countercurrent pretreatment have been on a prehydrolysis approach that seeks to maximize the hydrolysis of the hemicellulosic components of the feedstock, with little actual hydrolysis of the cellulose. The dilute acid countercurrent prehydrolysis process has shown significant performance improvements over dilute acid batch or cocurrent processes in terms of increased yields of xylose monomers and oligomers from xylan and enhanced enzymatic digestibility of the pretreated solids, resulting in higher yields of ethanol from cellulose in a shorter SSF residence time. Bench scale investigation of a dilute acid countercurrent prehydrolysis process using yellow poplar sawdust has been proven to be a superior pretreatment approach as compared to dilute acid batch and cocurrent processes. Both yields of soluble sugars from xylan and yields and rates of enzymatic digestibility in the pretreated solids are significantly improved. Although the reactor configuration is likely to be more expensive than for a batch or cocurrent prehydrolysis reactor and steam demands are significantly higher, preliminary process economic analysis indicate that the superior yields of the countercurrent process more than compensate for the higher reactor cost and steam requirements. Not only does the key activity entitled "Develop countercurrent chemical prehydrolysis technology" focus on bench scale testing, but its major efforts are involved in scaling up this technology to engineering-scale process equipment. It has been recognized that a countercurrent reactor design for a large scale process will be significantly more complex than the series of percolation reactors used in bench scale studies to date. The ability to achieve the contacting and movement of liquid and solids in an effective manner in a large scale device is a major challenge and will likely determine the ultimate commercial success of this pretreatment technology.

A number of feedstocks are slated for bench scale testing of countercurrent chemical prehydrolysis technology. Efforts on hardwood sawdust, the model feedstock that has been used for the development efforts for this technology for the past year, will be completed in early 1997. Data from this feedstock will provide the basis for the design of a prototype engineering scale countercurrent prehydrolysis reactor. Softwoods, which have been identified as a likely near term market for partnership development , will be tested on the bench scale in early to mid 1997. Finally, switchgrass, the selected mid term feedstock, will be evaluated on the bench scale through the end of 1997. In addition, the feasibility of a pressurized hot water countercurrent prehydrolysis process that uses no added acid catalyst will be investigated on appropriate feedstocks.

In recent months, the general concept of dilute acid countercurrent prehydrolysis (focusing only on hemicellulose hydrolysis) has been extended to investigate the possibility of a full hydrolysis of both hemicellulose and cellulose to soluble sugars. This key activity is entitled "Develop countercurrent complete chemical hydrolysis technology." This concept has been motivated by a number of factors. First, costs of commercial cellulase preparations from industrial enzyme suppliers have been prohibitive for use in bioethanol conversion processes. Although on-going process development and future research plans at NREL show promise in substantially reducing cellulase production costs, it is unclear at this time what the ultimate costs of cellulase production costs will be. Thus, a full hydrolysis process that substantially reduces or even eliminates cellulase requirements is an option worthy of investigation. Also, a bioethanol production process that includes a cellulase production unit operation adds a level of biotechnology complexity that some potential customers of bioethanol technology may wish to avoid. A non-enzyme based process would provide a technology package that addresses this need.

The use of dilute sulfuric acid to totally hydrolyze the carbohydrates in lignocellulosic feedstocks for ethanol production has been investigated in the past at NREL and by other researchers. Although kinetic modeling exercises have suggested that yields as high as 88% could be obtained using a counter-current reactor configuration, laboratory studies could only demonstrate total sugar yields (both C5 and C6 sugars) of about 60% in these earlier studies. Chromium leaching from the alloys used in these reactors, which will catalyze the sugar degradation reactions, and non-ideal flows due to the collapsing of the biomass particle bed as the particles lose their structural integrity at extensive levels of hydrolysis are observations that can explain these relatively low yields. Kinetic modeling exercises have also suggested that reducing the residence time of the dilute acid liquor (which contain the solubilized sugars) relative to the residence time of the solid biomass particles in a countercurrent mode can result in high yields of both xylose and glucose from xylan and cellulose, respectively. In a standard countercurrent reaction scheme, this would require very high quantities of dilute acid solution, resulting in excessive steam requirements necessary to heat the dilute acid solution to required temperatures and very dilute sugar concentrations in the hydrolysis liquor, increasing fermentation vessel volumes and increasing ethanol recovery costs.

A recent development, the continual shrinking bed reactor (CSBR), takes advantage of the fact that the biomass bed shrinks as the carbohydrate components are hydrolyzed. This allows an increased linear velocity of the hydrolysis medium as a function of time while keeping the overall volumetric flow of liquor at an economically acceptable level. Preliminary investigations using a series of bench scale percolation reactors equipped with internal springs to continually shrink the biomass bed, configured in a manner to simulate true countercurrent movement of liquid and solid, have shown that it is possible to achieve the yields of glucose and xylose suggested by the kinetic modeling. Additional work is needed to reduce the overall volume of hydrolysis medium required and to better understand the overall economic implications and trade-offs between a enzyme-based prehydrolysis process and a no enzyme-based full hydrolysis process. Thus far, the only feedstock tested in this reactor scheme has been yellow poplar sawdust. Again, a staged development effort that follows bench scale testing of yellow poplar sawdust with softwoods and then switchgrass will be conducted. At this time, hot water full hydrolysis approaches are not being seriously considered due to the very high temperatures that are required to achieve cellulose hydrolysis without an acid catalyst.

As with the countercurrent prehydrolysis efforts, the countercurrent complete hydrolysis activities have a major focus around engineering scale equipment design and testing. The ability to achieve the contacting of reaction fluid and solid particles are essential in the performance of this process, so an understanding of how to accomplish this in real scale process equipment is necessary. It is possible that equipment needed for the cellulose hydrolysis reaction can be added as a follow-on step to the countercurrent prehydrolysis reactors that will have already been developed.

Activities related to "Alternate Pretreatment Evaluation" are also a high priority. A number of such technologies have been investigated by many researchers, including many recently funded through a series of NREL subcontracts. A soon-to-be-completed evaluation of the data from these subcontracts will serve as the basis for developing a strategy and conducting follow-on bench scale improvements, potentially leading to engineering scale equipment design and testing. A key goal of the alternate pretreatment technology evaluation is to determine which pretreatment technologies are best suited to the various feedstock options.

Although the 2005 deployment target identifies switchgrass as the mid term feedstock, it is likely that long term energy crops such as short rotation hardwoods will become available at some point shortly thereafter. Thus, "Long term feedstock (hardwood) bench scale development" activities must be initiated within the time frame of the MYTP. Finally, the significant R&D efforts that will be completed during the next 3-5 years are likely to spawn a number of new pretreatment approaches that could produce more efficient, cost-effective, and more environmentally-friendly processes. These "Long range advanced pretreatment technologies" will be identified, developed and evaluated on the bench-scale, and scaled up in the out years of the MYTP.

A brief description of each detailed activity follows, including name of activity, description of the activity, description of metrics for that particular activity, and important relationships to other activities leading to near term or mid term deployment.

This set of activities is associated with the key activity entitled "Develop countercurrent chemical prehydrolysis technology"

6.5.4.1 Bench scale development of countercurrent chemical prehydrolysis. *

This work will include not only development of the actual prehydrolysis parameters, but also development of appropriate detoxification methods and fermentability testing using the appropriate fermentative microorganism. Various feedstocks will be tested in a sequential manner including hardwood sawdust and softwoods for near term deployment and switchgrass for mid term deployment. Process engineering metrics will be used to determine the performance parameters that are necessary to achieve successful completion of this activity. The process conditions identified will be of great importance to the design of a prototype prehydrolysis reactor (ID 120.)

6.5.4.2 Supply test quantities of pretreated feedstocks for other unit operations. *

As bench scale processes begin to generate representative prehydrolysate liquors and pretreated solids, these materials will be supplied to other research efforts, primarily the enzyme technology and fermentation organism development efforts. This activity is primarily a service function with no specific metrics associated with it.

6.5.4.3 Design and procure a prototype reactor. *

As bench scale process conditions and requirements are identified, this information will be used to design an engineering scale prototype prehydrolysis reactor system. This will be done in conjunction with previously identified industrial partners that will ultimately manufacture the reactor system. The reactor system will also be manufactured and delivered to the NREL PDU and the necessary time periods to conduct these tasks have been considered. The metric is the delivery of such a reactor system to the PDU. Follow on activities associated with installation and testing of this prototype system cannot commence until the reactor is delivered.

6.5.4.4 Modify, expand PDU and install and shakedown all equipment. *

Any engineering scale countercurrent prehydrolysis reactor will likely have significant space requirements in the PDU, so either rearrangement of existing equipment in the PDU or perhaps a small expansion of the PDU may be necessary. Also, ancillary equipment needed to operate the entire system will need to be obtained and the entire system will need to installed and shaken down. Successful operation of the entire system by the planned end of this activity is the key metric.

6.5.4.5 Test and modify prototype reactor. *

Once the prototype countercurrent prehydrolysis reactor system is installed and operational, it will be tested under a variety of reaction conditions. Results of this testing will likely indicate what modifications to the system will lead to improved performance. The key metric with this activity is a quantification of prehydrolysis performance improvement as a result of any reactor system modifications.

6.5.4.6 Hand-off prototype to EPD for integrated testing. *

Once satisfactory performance has been achieved, operation of the prototype prehydrolysis reactor system will be handed off to the EPD team, which will then operate the system to determine the impact of the prehydrolysis operation on subsequent unit operations.

6.5.4.7 Design second generation reactor. *

Once operation of the prototype reactor system is complete, the knowledge gained will be used to design an improved, second generation countercurrent prehydrolysis reactor system. Again, this will be done in conjunction with previously identified industrial partners that will ultimately manufacture the reactor system. Follow on activities associated with the procurement and installation of this second generation system cannot commence until the reactor is delivered.

6.5.4.8 Procure second generation reactor. *

After design is complete, the second generation reactor system will be manufactured and delivered to the NREL PDU. The metric is the delivery of such a reactor system to the PDU. Follow-on activities associated with installation and testing of this second generation system cannot commence until the reactor is delivered.

6.5.4.9 Install and shake down second generation unit. *

The second generation system and any additional ancillary equipment needed to operate the system will be installed and shaken down. Successful operation of the entire system by the planned end of this activity is the key metric.

6.5.4.10 Test and modify second generation unit. *

As with the prototype countercurrent prehydrolysis system, the second generation system will be tested under a variety of reaction conditions. Results of this testing will likely indicate what modifications to the system will lead to improved performance. The key metric with this activity is a quantification of prehydrolysis performance improvement as a result of any reactor system modifications, coupled with a preliminary process economic evaluation of this technology option based upon the performance parameters achieved in the engineering scale reactor system.

6.5.4.11 Hand off second generation unit to EPD for integrated testing. *

Once satisfactory performance has been achieved, operation of the second generation prehydrolysis reactor system will be handed off to the EPD team, which will then operate the system to determine the impact of the prehydrolysis operation on subsequent unit operations.

This next set of activities is associated with the key activity entitled "Develop countercurrent complete chemical hydrolysis technology"

6.5.4.12 Bench scale development of countercurrent complete chemical hydrolysis. *

This work will include not only development of the actual complete hydrolysis parameters, but also development of appropriate detoxification methods and fermentability testing using the appropriate fermentative microorganism. Various feedstocks will be tested in a sequential manner including hardwood sawdust and softwoods for near term deployment and switchgrass for mid term deployment. Process engineering metrics will be used to determine the performance parameters that are necessary to achieve successful completion of this activity. The process conditions identified will be of great importance to the design of an engineering scale full hydrolysis reactor.

6.5.4.13 Design complete hydrolysis reactor. *

As bench scale process conditions and requirements are identified, this information will be used to design an engineering scale full hydrolysis reactor system. It is likely that the second generation prehydrolysis reactor system can serve as the front end of a full hydrolysis system. This will be done in conjunction with previously identified industrial partners that will ultimately manufacture the reactor system. The metric is the delivery of such a reactor system to the PDU. Follow on activities associated with procurement and installation of this system cannot commence until the reactor is delivered.

*6.5.4.14 Procure complete hydrolysis reactor.**

After design is complete, the full hydrolysis reactor system will be manufactured and delivered to the NREL PDU. The metric is the delivery of such a reactor system to the PDU. Follow on activities associated with installation and testing of this system cannot commence until the reactor is delivered.

*6.5.4.15 Install and shakedown complete hydrolysis reactor.**

The complete hydrolysis reactor system and any additional ancillary equipment needed to operate the system will be installed and shaken down. Successful operation of the entire system by the planned end of this activity is the key metric.

*6.5.4.16 Initial testing and modification of complete hydrolysis reactor.**

The full hydrolysis reactor system will be tested under a variety of reaction conditions. Results of this testing will likely indicate what modifications to the system will lead to improved performance. The key metric with this activity is a quantification of hydrolysis performance improvement as a result of any reactor system modifications, coupled with a preliminary process economic evaluation of this technology option based upon the performance parameters achieved in the engineering scale reactor system.

*6.5.4.17 Hand off complete hydrolysis unit to EPD for integrated testing.**

Once satisfactory performance has been achieved, operation of the complete hydrolysis reactor system will be handed off to the EPD team, which will then operate the system to determine the impact of the complete hydrolysis operation on subsequent unit operations.

This next set of activities is associated with the key activity entitled "Alternate pretreatment evaluation" .

*6.5.4.18 Complete data analysis and process economic evaluation of alternate pretreatments.**

The series of alternate pretreatment techniques that have recently been completed by subcontractors and the data obtained for each method is currently being evaluated and a common-basis process economic evaluation is being performed. The key metric for this activity is to recommend which alternate pretreatment method(s) should be further optimized and perhaps, scaled up.

6.5.4.19 Develop strategy for follow-on alternate pretreatment work. *

Once the alternate pretreatment method(s) that merit further study have been identified, a strategy to take these methods(s) to the next level of bench scale development and perhaps, scale up testing, will be developed. A clear strategy where these method(s) are well integrated with other elements of the near and mid term deployment strategy is the key metric for this activity.

6.5.4.20 Further development/scale up/testing of selected promising alternate pretreatments. *

Any additional bench scale testing of the selected alternate method(s) will be followed by the design, acquisition, and testing of these method(s) in an appropriate engineering scale system. The key metric for this activity is the completion of data collection to allow for a comparison with the engineering scale data collection efforts for countercurrent prehydrolysis and full hydrolysis activities.

The next set of activities is associated with the key activity entitled "Long term feedstock (hardwood) bench scale development". Although these activities are not directly related to near term and mid term deployment goals with respect to the feedstock, it is clear that initial process development work on long term feedstocks will need to be initiated within the time frame of the MYTP.

6.5.4.21 Identify and obtain representative hardwood samples. *

The appropriate long term energy crop feedstock, presumably a short rotation hardwood species, will need to be identified and representative samples of this feedstock will be obtained for bench scale process testing.

6.5.4.22 Determine countercurrent prehydrolysis parameters for hardwood. *

This activity will be similar to the bench scale development work conducted for near term and mid term feedstocks. Prehydrolysis yields, fermentability performance, and process engineering metrics will be used to determine the performance parameters that are necessary to achieve successful completion of this activity. As standard conditions are developed, standard prehydrolysates will be supplied to the detoxification efforts listed below.

6.5.4.23 Determine best available detoxification methods for hardwood prehydrolysates. *

The release of potentially toxic compounds as a result of the prehydrolysis reaction is likely to vary with different feedstocks, both in the type of compounds released and the concentration of those compounds. Achieving pre-determined fermentation performance on detoxified prehydrolysates is the key metric for this activity. The potential cost of proposed detoxification options will also be quantified and used to select economically viable detoxification options.

6.5.4.24 Quantify material balance, solids digestibility, and fermentability of standard detoxified prehydrolysate. *

Once standard conditions for countercurrent prehydrolysis of hardwood and detoxification of prehydrolysates have been determined, the "standard process" will be evaluated in detail to quantify all performance parameters and establish a material balance. The key metric for this activity will be the determination of performance parameters and material balance for the "standard" prehydrolysis/detox/solids digestibility/prehydrolysate fermentability "integrated" process for hardwood.

6.5.4.25 Determine countercurrent complete hydrolysis parameters for hardwood. *

This activity will be similar to the bench scale development work conducted for the prehydrolysis hardwood process, but will focus on the full hydrolysis option. Hydrolysis yields, fermentability performance, and process engineering metrics will be used to determine the performance parameters that are necessary to achieve successful completion of this activity. As standard conditions are developed, standard hydrolysates will be supplied to detoxification efforts listed below.

6.5.4.26 Determine best available detoxification methods for hardwood complete hydrolysates. *

The release of potentially toxic compounds as a result of the full hydrolysis reaction is likely to vary with different feedstocks, both in the type of compounds released and the concentration of those compounds. Achieving pre-determined fermentation performance on detoxified hydrolysates is the key metric for this activity. The potential cost of proposed detoxification options will also be quantified and used to select economically viable detoxification options.

6.5.4.27 Quantify material balance, solids digestibility, and fermentability of standard detoxified complete hydrolysate. *

Once standard conditions for the complete hydrolysis of hardwood and detoxification of hydrolysates have been determined, the "standard process" will be evaluated in detail to quantify all performance parameters and establish a material balance. The key metric for this activity will be the determination of performance parameters and material balance for the "standard" full hydrolysis/ detoxification/ hydrolysate fermentability "integrated" process for hardwood.

6.5.4.28 Conduct preliminary process engineering analysis of hardwood countercurrent pretreatment. *

The determination of bench scale process performance yields and material balances for the countercurrent prehydrolysis and full hydrolysis options for hardwood will be used in a preliminary process engineering analysis. The key metric will be a recommendation of which option is potentially more economically viable in a full scale process.

*6.5.4.29 Scale up modification/testing in appropriate countercurrent PDU reactor.**

Once a determination of which pretreatment option (prehydrolysis vs. complete hydrolysis) is better suited for the hardwood feedstock, a scale up testing phase of this technology will be conducted. It is likely that the engineering scale prehydrolysis or full hydrolysis system described above for other feedstocks will be suitable for this activity, but may need some modification for potential difference in reaction conditions or feedstock handling characteristics. This activity will generally follow the logic of similar efforts for near and mid term feedstocks that have been described above, with similar metrics for task completion.

This final set of activities is associated with the key activity entitled "Long range advanced pretreatment technologies". Again, although these activities are not directly related to near term and mid term deployment goals, initial process development work on advanced pretreatment technologies will be initiated within the time frame of the MYTP.

*6.5.4.30 Identify advanced pretreatment technologies.**

It is likely that based on the knowledge gained in developing bench scale and engineering scale countercurrent prehydrolysis, complete hydrolysis, and alternate pretreatment approaches described above, advanced pretreatment options will become apparent. Such technologies would presumably offer some performance, cost, or environmental advantages. In this activity, such pretreatment approaches will be considered and a small number will be recommended for bench scale evaluation. The metrics used to select advanced pretreatment options will include potential performance improvements and/or cost savings over the existing pretreatment options.

*6.5.4.31 Conduct bench scale development program on selected advanced pretreatment technologies.**

This work will include not only development of the actual pretreatment parameters, but also development of any necessary detoxification methods and fermentability testing using the appropriate fermentative microorganism. Feedstock selection will be based upon the best feedstock opportunities that will exist 2-4 years beyond the time frame of this effort, allowing time for scale up and demonstration of this technology prior to commercialization. Process engineering metrics will be used to determine the performance parameters that are necessary to achieve successful completion of this activity. The process conditions identified will be of great importance to the design of an engineering scale reactor.

*6.5.4.32 Identify and obtain appropriate engineering scale reactor for advanced pretreatment technology.**

The design and acquisition of advanced pretreatment technologies in an appropriate engineering scale system will then be performed. This activity will likely be conducted in partnership with potential pretreatment equipment vendor(s). The key metric for this activity is the shake down and initial operation an engineering scale pretreatment system based upon one or more of these advanced pretreatment methods.

*6.5.4.33 Testing of advanced pretreatment technologies at PDU scale.**

Once the engineering scale advanced pretreatment system is installed and operational, it will be used to collect the appropriate performance data. The key metric for this activity is the completion of data collection in the engineering scale system to allow for a comparison with other previously demonstrated pretreatment technologies.

6.5.5 Enzyme R&D

FY2000 EDU Enzyme R&D

*6.5.5.1 T. reesei: Decrease cellulase cost by optimizing induction protocols.**

The enzymatic saccharification of cellulosic biomass by the T. reesei enzyme complex has been shown to be more effective when the microorganism is grown in the presence of the biomass substrate it will ultimately saccharify. Cellulases grown on soluble sugars and bioethanol process streams will be compared for their ability to hydrolyze pretreated hardwoods using traditional (filter paper assay) and novel methods (DSA assay). Various cost effective induction protocols will be investigated and optimized utilizing programmatic feedstocks (pretreated hardwood sawdust) and cheap sugars, such as acid-hydrolyzed starch. The development of a more effective T. reesei cellulase system should impact the amount of total protein loading required for the process and therefore result in a net savings to the cost of ethanol production from biomass.

6.5.5.2 P Milestone-Deliver new protocols to EPD (6/30/97).

The results from these studies will be communicated to the ethanol process development (EPD) team for economic analysis and implementation.

6.5.5.3 T. reesei: Determine effects of induction protocols on component enzymes.

In order to better understand the relationships between effective induction of T. reesei cellulase complexes and specific feedstocks, characterization of the key enzyme component profile of each newly induced system is required. Characterization of the enzymatic proteins induced by soluble sugars and those induced by process derived substrates and products will be compared. To accomplish this goal, a method of fingerprinting the T. reesei cellulase system will be developed or adapted, likely candidate methods being capillary electrophoresis, western blots, and/or activity assays. The information generated from this study will be utilized to set future directions for the advanced cellulase system work. For this activity, success is defined as the development of correlations between enzyme component mix and overall cellulase (enzyme) complex effectiveness.

FY2005 EDU Enzyme R&D

Develop Cost Effective Enzyme Systems for Pretreated Switchgrass.

A phased plan to develop an engineered cellulase system which can be optimized for maximal efficiency on pretreated biomass, specifically switchgrass, and produced at a cost of approximately one-third that of traditional sources of T. reesei enzyme. The Phase I new cellulase system will comprise a highly active, thermal tolerant endoglucanase and two mesophilic exoglucanases. In order to operate effectively as a system, the latter two enzymes will be rendered more thermal stable using site-directed-mutagenesis (SDM) methodologies. All three enzymes will also be modified for improved function on biomass surfaces using SDM. Two years after initiation, this new system should be ready for integrated testing at elevated temperature. Following successful testing, further improvements in enzyme performance are planned in Phase II, where improved crystallographic structures and kinetic modeling should permit improvements in enzyme specific activity by strategic active site modification. The so-called, accessory enzymes (xylanases, xylan acetyl esterases, cellodextrinases, etc), will also be considered for efficacy in the presence of cellulases for the hydrolysis of pretreated switchgrass. Finally, advanced enzyme production technology using plant hosts will be investigated in detail with subcontractor assistance. An effort initiating in early FY98 will further assess recombinant cellulase production in submerged culture with the support of a subcontractor or industrial partner. At 10/1/98 a decision regarding cellulase expression hosts will be made and work following this event will focus on the winner. At 10/1/01 a decision is scheduled to determine if the Phase II engineered recombinant cellulase system is sufficiently meritorious to warrant further expression/production studies in plants or submerged culture. If found unsuccessful, a decision to develop a new biochemical strategy for advanced cellulase systems may be proposed, or enzyme use may be omitted completely in favor of advanced pretreatment options.

6.5.5.4 Phase I-Improve action of EI on pretreated switchgrass using site-directed mutagenesis (SDM). *

This activity will be initiated with a two-month strategy development period during which NREL staff and an external consultant will develop a detailed experimental plan to improve EI. This work will target the maximization of the reaction kinetics that depend on optimal enzyme residence on the substrate surface. We will replace targeted surface amino acids on the EI catalytic domain in order to reduce the very strong (dead-end) binding complexes, as well as the strong surface repulsion interactions; both of which lead to reduced enzyme efficiency. We will also conduct proline replacement and packing density improvement studies using SDM which should increase the thermal tolerance of this already thermophilic enzyme. The second year of activity will incorporate new structural information a second round of mutation strategies. Success is defined in terms of improvements in k_{cat} or other related kinetic constants for EI acting on pretreated switchgrass--specific targets to be determined early in the experimental phase. The hand-off at 10/1/98 will contribute to the engineered cellulase system.

6.5.5.5 Phase I-Increase T_{opt} and process tolerance of CBH I using SDM. *

This activity is designed to transform *T. reesei* CBH I into a thermal tolerant exoglucanase so it can be used optimally with EI at elevated temperatures. Classical strategies in enzyme engineering will be used to modify CBH I for this purpose (similar to those proposed above for EI). A key hurtle for CBH I SDM at NREL is the development of a suitable expression system for this fungal enzyme. *T. reesei* and/or *A. niger* are ideal for this purpose; yeast expression systems tend to hyper-glycosylate and bacterial expression systems tend to autolyse cellulases. Recombinant CBH I demonstrating enhanced thermal stability of 10 or more degrees C will be considered a measure of success for Phase I. A second year of effort will follow improved methods and results from the first year; eventually, CBH I should function with suitable half-life at 70°C. A hand-off at 10/1/98 to integrated testing is also proposed for improved CBH I.

6.5.5.6 Perform substrate/cellulose binding domain modeling for CBH I. *

This subcontracted effort will contribute new information concerning cellulase cellulose binding domain (CBD)/cellulose interaction to the CBH I SDM effort using computer modeling. Answers to questions about the strength of this binding as a function of temperature and specific CBD binding-surface chemistry are considered measures of success. This work will support the two-year phase I SDM effort at NREL.

6.5.5.7 Increase Topt and process tolerance of E3 using SDM.*

The thermal tolerance of E3 will also be improved using SDM methods by a subcontractor. As in the case of rCBH I, E3 modification will be considered successful if the T_{opt} can be increased to approximately 70°C, or if the half-life at this temperature can be extended to a process relevant period by the end of the second year of SDM work. As for rEI and rCBH I, rE3 will be ready for a hand-off to integrated testing at 10/1/98.

6.5.5.8 Provide high resolution x-ray structures for E3 and clones of EI.*

High resolution x-ray crystallographic structures of EI and E3 are required for advanced SDM efforts. A subcontractor will continue to improve the current 2.4 angstrom structure for EI and initialize crystallization work on E3. The subcontractor will also develop new structures of recombinant EI derived from SDM at NREL that appears promising. Success is defined by the numbers of new crystallographic structures solved.

6.5.5.9 Report K Milestone describing cellulase improvement by SDM*

(10/1/98). Report success of Phase I improvements in cellulases subjected to SDM strategies.

6.5.5.10 Deliver Phase I engineered cellulase system to EPD for testing.*

Produce and deliver a sufficient quantity of recombinant EI, CBH I, and E3 (approximately 10-50 mg each) to EPD for integrated testing on pretreated switchgrass.

6.5.5.11 DECISION: Pick plant or submerged culture expression-continue w choice.*

Focus efforts on recombinant cellulase expression of either terrestrial plants or classical fungal or bacterial submerged culture.

6.5.5.12 Develop strategy to improve active site performance of cellulases.*

This subcontracted effort will gather together and assess pertinent data to generate a strategy for the improvement of the active sites of glycosyl hydrolases in general, and cellulases specifically. This study will produce a recommendation that will be used directly for Phase II cellulase SDM work.

6.5.5.13 Phase II: Increase specific activity of rCBH I on pretreated switchgrass using SDM.*

Using the recommendations from previous activities, develop and test strategies to alter the active site or other elements of enzyme structure for the purpose of increasing specific activity. Success will be measured as demonstrable increases in kcat or other appropriate kinetic constants using pretreated switchgrass as substrate.

6.5.5.14 Phase II: Increase specific activity of rE3 on pretreated switchgrass using SDM.*

Develop and test strategies to alter the active site or other elements of enzyme structure for the purpose of increasing specific activity. Success will be measured as demonstrable increases in kcat or other appropriate kinetic constants using pretreated switchgrass as substrate.

6.5.5.15 C Milestone-Deliver Phase II engineered cellulase system with accessory enzymes to EPD for testing.*

Sufficient quantities of improved, recombinant EI, CBH I, and E3 cellulases will be produced and delivered to EPD for integrated testing on pretreated switchgrass. Work to assess the requirement for accessory (non-cellulase) enzymes, Activity 163, will also contribute to the construction of this system.

6.5.5.16 DECISION: Pick enzymes or DMC *

Pick the process configuration using free cellulases in combination with an ethanologen or a configuration using ethanologens capable of fermentation and production of cellulases, *i.e.*, DMC.

6.5.5.17 Produce rEI, rCBH I, and rE3 in 1st Generation plants.*

A subcontractor or NREL partner will develop or adapt an expression system useful for the large scale production of recombinant cellulases in terrestrial plants (crops). It is anticipated that this new technology will be owned by the subcontractor or partner and ultimately made available to others through licensing agreements.

6.5.5.18 Evaluate field tests and enzyme recovery schemes.*

The second year of this subcontracted effort will be the field-testing phase. Recombinant cellulases supplied by NREL will be produced in transgenic plants at intermediate scale so that production economics can be estimated. Technologies for recovering transgenic enzymes from plant tissue at large scale will also be evaluated.

6.5.5.19 Produce rEI, rCBH I, and rE3 in 2nd Generation plant systems.*

Following successful testing of first generation plants at both greenhouse and field scales, develop and employ improved plant expression system(s) referred to as 2nd Generation systems.

6.5.5.20 Produce improved rEI, rCBH I, and rE3 in best field crops.*

Following substantial success in production of Phase I cellulases from Generation 2 plants, transform or transfect best plant systems with genes coding Phase II improved cellulases.

6.5.5.21 Evaluate field tests and enzyme recovery schemes.*

An NREL activity to evaluate all data from subcontractor testing to determine potential for economical production of cellulases from plants. This activity is subject to the decision to select free enzymes or DMC technology.

6.5.5.22 C Milestone-Deliver technology for plant produced cellulases to EPD for modeling and testing.*

This milestone will deliver the combined technology for production of improved cellulases from plants (or submerged culture depending on Decision) to the EPD for integrated testing.

6.5.5.23 Determine utility of accessory enzymes (i.e., xylanases, cellodextrinases, etc) for hydrolysis of pretreated switchgrass.*

New pretreatment schemes, such as countercurrent dilute acid hydrolysis, will produce solid and soluble biomass fractions which contain polysaccharides not readily hydrolyzed by cellulases alone. Xylooligodextrins and cellodextrins (some modified) have been identified preliminarily in these process streams. This activity will examine the utility of non-cellulase hydrolases for the depolymerization of these oligomers. Success will be demonstrated by discovery that non-cellulases can be effective, or that the oligomers are essentially non-digestible (i.e., chemically modified).

6.5.5.24 Provide purified accessory enzymes for testing at NREL.*

This subcontract will provide special accessory enzymes in milligram quantities for testing at NREL.

6.5.5.25 Improve T_{opt} and process tolerance of accessory enzymes by SDM.*

If the need for accessory enzyme(s) is established as a result of Activity 164, then an SDM effort will be initiated to bring these enzymes into thermal compatibility with the improved rCBH I and rE3..

6.5.5.26 Produce native or early Phase I rEI, rCBH I, and E3 in submerged culture (Aspergillus, Trichoderma, or Pichia).*

This subcontracted effort will adapt commercially viable expression systems for production of the engineered cellulase component enzymes. This work may be accomplished optimally with an NREL/industry partnership. Initial work can target individual gene expression, whereas follow-on work in FY98 may address the possible expression of bi- and tri-genic expression. This activity should start in late 1997 or early 1998 in order to take advantage of early Phase I improved cellulases.

6.5.5.27 Produce Phase I rEI, rCBH I, rE3, and/or accessory enzymes in submerged culture.*

Production scale testing of the best Phase I cellulases in submerged culture. At this point, the most promising submerged culture host system for production of cellulases should be known.

*6.5.5.28 Evaluate Generation II submerged culture production technologies with industry.**

This activity is proposed as a partnership with an industrial producer of enzymes. The specific objective is to transfer large scale production of improved recombinant cellulase systems to commercial scale, thus supporting the bioethanol industry.

*6.5.5.29 C Milestone-Deliver mature technology for submerged culture production to EPD for modeling and testing.**

6.5.6 Fermentation Strain R&D*

The goal of the Strain Development Team (SDT) is to develop microbial catalysts that effectively convert a variety of sugar streams from hardwood sawdust (near-term feedstock) and herbaceous energy crop switchgrass (mid-term feedstock) to ethanol. Our previous in-house research efforts have focused almost exclusively on the development of *Zymomonas mobilis* as our primary ethanologen. This bacterium's high conversion yield, fermentation selectivity and ethanol tolerance levels are key attributes for a commercially viable ethanol-producing strain. To develop this organism for conversion of mixed hexose and pentose sugar streams derived from lignocellulosic feedstocks, we have successfully metabolically-engineered this organism to include xylose utilization as well as arabinose utilization.

To further develop *Zymomonas* for a year 2000 waste to ethanol facility, we need to develop a glucose-, xylose- and/or arabinose-cofermenting *Zymomonas* strain with increased stability and robustness. The current plasmid-bearing xylose-fermenting *Zymomonas* strain is stable for a batch SSCF process. However, we anticipate that plasmid stability could be problematic in an integrated continuous process or in high soluble glucose feed streams without selective pressure (*i.e.*, an antibiotic). We are developing methodologies for chromosome integration in *Zymomonas* and are hoping to introduce the pentose-fermenting genes into the *Zymomonas* chromosome without the need for an antibiotic resistance gene so that the strain will be stable and thus more desirable in a commercial process. We would like to evaluate and characterize current, ostensibly hydrolysate, acid, thermal, or ethanol tolerant strains and hope to introduce pentose fermentation capabilities into them and eventually integrate the pentose-fermenting genes into the chromosome. In addition, we will investigate new approaches to improve pentose-fermenting strains, such as identifying and modifying metabolic bottlenecks for enhancing productivities, introducing improved pentose transport systems, developing strategies for minimizing byproduct formation, and implement the strategies for developing a "super" glucose-, xylose- and/or arabinose-cofermenting *Zymomonas* strain. This organism will be provided for bench scale testing in second roll-out of improvements in technology by the end of year 2000.

We previously identified *Lactobacillus* as a promising ethanologen requiring longer-term research before it would meet commercial needs. We selected strain Mont4 primarily because of its ability to homofermentatively convert a large variety of sugars, including arabinose and cellobiose, almost exclusively to lactic acid. In addition, the wild-type Mont4 is thermotolerant and can grow in the presence of 80% poplar wood hydrolysate. During the past two years we engineered Mont 4 for homolactic acid production from xylose by introducing the xylose pathway into it. We deregulated at least one level of glucose catabolite repression of xylose utilization by mutagenizing the regulatory regions on the xylose operon. Our next step is to introduce the ethanol production genes (pet) and redirect the carbon flow from pyruvate to ethanol instead of lactic acid. This work was postponed due to budgetary constraints in FY96. In FY97 we would like to reinitiate this work by introducing ethanol production genes into Mont4 and assessing the capabilities of the recombinant strain.

We predict that the strong lactic acid dehydrogenase genes will need to be inactivated to avoid a mixed product fermentation. We anticipate that at least one other level of glucose catabolite repression will need to be removed for glucose-, xylose- and arabinose-cofermentation. We plan to provide the improved *Lactobacillus* for bench scale testing in the second roll-out of improvements in technology by the end of year 2000.

To develop an organism for use in the year 2005 switchgrass to ethanol facility, we will need to modify *Zymomonas* and *Lactobacillus* to be suitable for conversion of sugar streams from switchgrass. Although only one years worth of research activities are defined past the year 2000, it is anticipated that ongoing previous work will help guide our future research efforts. An improved strain will be provided to EPD for bench scale testing by the year 2000. Furthermore, by this time-frame a decision will be made to select the best overall organism for direct microbial conversion (DMC) strain development work.

*6.5.6.1 Develop Zymomonas organism for use in year 2000 waste to ethanol facility**

6.5.6.1.1 Evaluate new Zymomonas strains.*

Evaluate and characterize current, ostensibly hydrolysate, acid, thermal, or ethanol tolerant strains and introduce the xylose and arabinose fermentation capabilities into them in plasmid form. Evaluate pentose-fermenting *Zymomonas* strains for potential improvement in hydrolysate, acid, thermal, or ethanol tolerance. Evaluate *Zymomonas* strain with both xylose and arabinose-fermenting capabilities in a single plasmid.

6.5.6.1.2 Select strains for hand-off to integration studies.*

Select improved *Zymomonas* strains from the previous activity and hand-off to EPD for integration studies.

6.5.6.1.3 Develop chromosome-integrating capabilities in Zymomonas strains (addition of a new activity start from 10/1/96 through 9/30/97)

Integrate two xylose-assimilating and two pentose-phosphate pathway genes into the *Zymomonas* chromosome through single and double integration events via transposon or homologous recombination (through subcontract) for a stable strain. Use potential hydrolysate, acid, thermo, or ethanol tolerant strains identified in previously as hosts for integration if identified.

6.5.6.1.4 Develop further improvements in Zymomonas.*

Integrate additional three arabinose-assimilating genes into xylose-fermenting strain. We may have to construct a separate chromosome integrated arabinose-fermenting strain if multiple integration events are not feasible in *Zymomonas*. Evaluate the chromosome integrated strains for mixed-sugar fermentation.

6.5.6.1.5 Hand-off improved Zymomonas strain for pilot scale demonstration work with industrial partner*

Hand-off of chromosome-integrated strains to EPD for bench scale testing in the first roll-out of improvements in technology by the end of FY98.

6.5.6.1.6 Investigating new approaches to improve Zymomonas strains *

The current xylose-fermenting *Zymomonas* strains showed limited fermentation performance under certain "stress" (realistic) conditions such as at low pH, high temperature and ethanol concentration, and in the presence of hydrolysates. "Stalled" xylose fermentation was observed at high sugar loading, resulting in byproduct formation. This could be due to ethanol sensitivity. To address these we will investigate new approaches to improve the *Zymomonas* strain. These include:

- Investigate the needs for replacement of *E. coli* genes in *Zymomonas*
- Evaluate and embellish improved xylose-transport systems (through subcontract in FY96-FY97)
- Determine utility of introducing stress proteins in Zymomonas through subcontract
- Begin transport studies with arabinose through subcontracted efforts

- And, develop strategies for minimizing byproduct formation.

These results will provide recommendations for improving *Zymomonas* in the next two activities.

6.5.6.1.7 Begin making metabolic enhancements of Zymomonas*

We will start metabolic flux studies. From these we will identify and begin correcting metabolic bottlenecks for enhanced yield and productivity based on information obtained from the previous activity. To relieve these bottlenecks, we will adjust the gene expression levels for the key enzymatic steps through genetic manipulation to maximize metabolic flux.

6.5.6.1.8 Implement strategies to improve robustness of Zymomonas strain*

We will focus work on increasing the robustness (i.e., acid/ethanol tolerance) of *Zymomonas* based on information from subcontracts on stress protein studies. In addition, we will evaluate and embellish on an improved arabinose-transport system. Then, we will combine improved xylose and arabinose facilitated transport qualities into a single strain. Finally we will Implement a plan for reducing byproduct formation, such as xylitol and lactic acid, through targeted gene inactivation.

6.5.6.1.9 Develop a "super" Zymomonas strain with desired robustness and sugar utilization characteristics.*

Incorporate all the best qualities into single "super" *Zymomonas* strain with increased stability and robustness. We may need to build several *Zymomonas* strains for sugar feed streams which have different compositions and contents. We will evaluate newly constructed strains on hydrolysates as they become available.

6.5.6.1.10 Hand-off advanced Zymomonas strains to industrial partner for use in commercial facility.*

We will provide the advanced strain to EPD for bench scale testing in the second roll-out of improvements in technology by the end of year 2000.

6.5.6.2 Develop Zymomonas organism for use in year 2005 switchgrass to ethanol facility.

6.5.6.2.1 Make adjustments for switchgrass.*

The *Zymomonas* strain developed in the previous Activity should be able to convert the predominant sugars, glucose, xylose and arabinose, derived from switchgrass. As switchgrass hydrolysates become available, we will begin evaluation of *Zymomonas* fermentation performance on switchgrass and determine if we need to introduce galactose-fermenting genes into *Zymomonas*. Investigate/address the role of possible silica derived from switchgrass in *Zymomonas* growth. Modify the advanced strain for switchgrass if necessary.

6.5.6.2.2 Switchgrass strain to EPD for integration studies.

We will provide modified advanced strain to EPD for bench scale testing.

*6.5.6.3 Develop Lactobacillus for ethanol production**

6.5.6.3.1 Re-initiate work on Lactobacillus

The description of this activity is combined with next activity.

6.5.6.3.2 Develop an ethanol producing Lactobacillus*

During this two year period, we will isolate a strong, constitutive promoter for gene expression. Construct ethanol production operon (pyruvate decarboxylase, alcohol dehydrogenase (pet)) and introduce it into *Lactobacillus* Mont4. Evaluate the recombinant *Lactobacillus* for ethanol production. We will develop integration vectors for inactivation of lactate dehydrogenase gene eliminate lactate if necessary. Integrate ethanol production genes into chromosome for stabilization.

6.5.6.3.3 Hand-off Lactobacillus to EPD for integration studies.*

We will provide an ethanol-producing *Lactobacillus* to EPD for bench scale testing in year 2000. Note that this could be optional because no activities are schedule in EPD for testing in FY99.

6.5.6.3.4 Assess and improve Lactobacillus strains*

Evaluate the ethanol-producing Lactobacillus for cofermentation in mixed-sugars. We anticipate that at least one other level of glucose catabolite repression needs to be removed for cofermentation. We will identify and clone key genes and modify the regulatory elements for improvement. Evaluate improved Lactobacillus before hand-off to EPD.

6.5.6.3.5 Hand-off Lactobacillus to EPD for integration and pilot scale studies.

We will provide improved ethanol producing *Lactobacillus* to EPD for bench scale testing in year 2000.

6.5.6.4 Develop Lactobacillus strain for use in year 2005 switchgrass to ethanol facility.

6.5.6.4.1 Make adjustments for switchgrass sugars as needed.

The *Lactobacillus* strain developed should be able to convert the predominant sugars, glucose, xylose and arabinose, derived from switchgrass. As switchgrass hydrolysates become available, we will begin evaluation of *Lactobacillus* fermentation performance on switchgrass and determine if we need to introduce galactose-fermenting genes into *Lactobacillus*. Investigate/address the role of possible silica derived from switchgrass in *Lactobacillus* growth. Modify the advanced strain for switchgrass if necessary.

6.5.6.4.2 Hand-off switchgrass Lactobacillus strain to EPD for bench scale testing.

We will provide modified advanced strain to EPD for bench scale testing.

A decision will be made to using either improved *Zymomonas* or *Lactobacillus* for direct microbial conversion (DMC) strain development at the end of year 2001.

6.5.7 Direct Microbial Conversion Strain Development*

*6.5.7.1 Develop cost effective Zymomonas strains through DMC.**

The prospect of producing ethanologenic microorganisms capable of producing their own hydrolytic enzymes is indeed intriguing, yet still held with some speculation. The issue being metabolic load and the ability of a fermentative organism to produce ethanol at high yield and simultaneously produce and secrete enzymes in the 10-30 g/L range. One aspect of DMC that is technically feasible and attractive for FY2005 goals is the concept that a cellobiase can be expressed in *Zymomonas* to relieve the otherwise strong dependence of the fermentation on extraneous beta-glucosidase. Previous work with wild-type *Zymomonas mobilis* has shown that a bacterial beta-glucosidase and endoglucanase can be expressed at low levels and localized in the periplasmic space. These transformed *Zymomonas* strains can ferment cellobiose. Our ultimate objective is to utilize a more effective cellobiase than the beta-glucosidase chosen by other researchers, and to demonstrate a highly efficient *Zymomonas* capable of fermenting glucose, xylose, and cellobiose.

*6.5.7.2 Acquire or produce cDNA clone of best beta-glucosidase or cellobiase.**

This work will identify the best cellobiase from literature review, followed by the acquisition of the coding sequence for this enzyme by either generating cDNA from a genomic library, or sub-cloning screened lambda phage libraries. The option of simply procuring a gene coding for a promising cellobiase is also viable, considering the short time track proposed. Once acquired, the recombinant cellobiase will be produced in suitable laboratory host, purified, and verified for kinetic properties.

*6.5.7.3 Clone cellobiase in best Zymomonas using best available expression vectors.**

Once a viable coding sequence is available, it must be made transportable into *Zymomonas*. This will be done by constructing a custom expression vector, such as pZB209, with a suitable promoter and signal peptide region. If early work with wild-type *Zymomonas* is successful, then attention will turn to the metabolically engineered *Zymomonas* strain capable of fermenting glucose and xylose developed at NREL. Success is defined a producing a *Zymomonas* strain capable of fermenting cellobiose by 10/1/98.

6.5.8 Lignin Utilization*

Lignin will be an abundant byproduct of lignocellulosic biomass ethanol production via enzymatic or acid saccharification and fermentation of the carbohydrate fractions since 20 wt% of all lignocellulosic (dry basis) are lignin. Thus, this supply will progressively increase as ethanol plants using straw, forest residues, etc., as feedstocks, are implemented in the future. Currently, lignin from ethanol plants is planned to be burned. This project proposes converting the lignin to added value products. To do this, the strategy is to depolymerize the lignin to simple monomeric and oligomeric O-containing aromatic blocks (or clusters) and use them as valuable intermediates for upgrading chemically to higher value products.

Since 1994, Prof. Shabtai's group at the University of Utah has been working on the fundamentals of lignin depolymerization and upgrading to fuel additives. The project has generated a significant amount of very interesting data. A process flow sheet has been tentatively developed. In the Shabtai Lignin Process, the upgrading approach is hydrotreatment leading to cyclic and branched gasoline additives. Other upgrading approaches are also possible: catalytic oxidation to aldehydes and catalytic hydrolysis to phenols, catechols and similar hydroxylated aromatics.

The Shabtai Lignin Process consists of the following steps (from the 1994 - 96 work):

- Base catalyzed depolymerization (BCD) of lignin under the presence of an alcohol (methanol or ethanol). KOH has been used by the Utah group yet other bases are possible
- Recovery of the tar from the BCD step; Recovery of the KOH (or other base)
- Hydroprocessing (HPR) the tar to rupture C-C bonds which are responsible for the presence of oligomers. This step is catalytic and removes oxygen
- Selective hydrogenation of the ring (SRH), if desired, to reduce the aromaticity of the product.

In the Shabtai Lignin Process, the upgrading approach is hydrotreatment leading to cyclic and branched gasoline additives. Other upgrading approaches are also possible: catalytic oxidation to aldehydes and catalytic hydrolysis, or pyrolysis to phenols, catechols and similar hydroxylated aromatics.

The partial oxidation of lignin in the presence of a base (KOH, NaOH, etc.) and water using a mild oxidation catalyst, such as CuO, and oxygen (from air). Yields of aldehydes (a mixture of vanillin, syringaldehyde and benzaldehyde) of 25 wt% are possible along with other less valuable components. These yields have never been achieved industrially even if they are possible, because of lack of catalytic selectivity. The severity of the conditions used in this process is less than those of the Shabtai Lignin process.

The hydrolysis process uses a base and water to yield a mixture of phenol, catechol and hydroxylated substituted aromatics. The latter could be further upgraded after removal of the simpler molecules (via vacuum distillation). The severity of the conditions are similar to those used in the Shabtai Lignin process.

The pyrolysis process uses rapid heating and catalysis to break down lignin into a depolymerized lignin (DL) product which could be upgraded very much like the tar from the Shabtai Lignin process. Yields of DL tar of 60 - 70 wt% are possible operating at atmospheric pressure and up to 500 °C for a few seconds as residence time.

Since the Shabtai Lignin Process leads to an unique tar intermediate, i.e. the alkylated O-containing aromatics, we ought to start with this process as the one providing direct possibilities for the development of a new generation of gasoline enhancers. It is thus necessary that the Professor Shabtai's group participate in the study as the key subcontractor that will produce the basic data (depolymerization and upgrading) with which to carry out the different evaluations.

The selection of targeted chemicals, likely gasoline additives, will have to be made as a function of the market value, size and receptivity as well as the cost of the intermediate tar produced from the key depolymerization step. So, in order to guide subsequent stages of the work, a technoeconomic feasibility study will be carried out to provide directions for selecting experimental priorities to be funded. Therefore, it is recommended that the lignin strategy ought to be developed progressively aiming at the project activities described in the MYTP Gantt chart and described in the following sections.

*6.5.8.1 Technoeconomic assessment of lignin availability, types and gate price.**

Lignin from US chemical pulping operations will be inventoried. Descriptors will be: type of process, type of lignin, quantities produced, current uses, current prices and trends. Lignin availability from novel processes, such as ethanol from lignocellulosics and Organosolv pulping, will be estimated. It is understood that these processes do not commercially exist today. The contractor will specify the hypothesis that will permit to estimate production in the next few decades. Since lignin is normally produced via "wet processes" the contractor will have to determine the costs needed to dry the lignin to reasonable moisture contents (at 25 and 50 wt% as two prototype cases).

Impurities present in lignin during the production processes will also be determined and an assessment of possible downstream difficulties will be made.

This work will be carried out by NREL and a specialized subcontractor in resource assessment. Estimated time for completion is early CY1997.

6.5.8.2 Laboratory optimization of the BCD and Upgrading steps.

This task is the continuation of the work to be pursued by the Univ. of Utah team under the leadership of Prof. Shabtai and will likely be centered into two areas:

- The development of basic knowledge for the production of oxygenates via a three step approach: BCD + Etherification + Selective Ring Hydrogenation (SRH);
- The optimization of the BCD + HPR + Ring Hydrogenation (RH) process whose basic data was developed in the 1994 - 96 period.

This work will be carried out by the U. of Utah and will be technically monitored by NREL personnel over an anticipated two year period of 10/96 to 10/98. Results will be provided to Sandia National Laboratory (SNL) and NREL for technical evaluation.

6.5.8.3 Reproducibility and batch scale-up of the results obtained by the U. of Utah group

This Task will aim at determining the reproducibility of the U. of Utah results using facilities at Sandia. The objective is to work with larger autoclave systems and correspondingly larger amounts of feedstock, reactants and catalysts. Since the U. of Utah group has worked so far with 50 cc microautoclaves (although the lab is also ready to work with 300 cc autoclaves) the Sandia group ought to carry out experiments at prescribed conditions (by the NREL technical monitor) using larger autoclaves, adequately agitated. The autoclave volume ought to be such that batches of 250 to 500 g of lignin can be processed. This will represent a scale-up factor of 25 to 50 with respect to the work conducted in the 1994-96 period at the U. of Utah. Samples from these large batches will be characterized by NREL who will become the independent central analytical group.

This Task will be carried out at Sandia National Laboratory for an estimated to two years (10/96 to 10/98) prior to the beginning of any scale-up to a continuous reactor.

*6.5.8.4 Supply of lignin to U. of Utah and Sandia National Laboratories**

The Ethanol Project will be conducting various pilot plant testing to the enzymatic hydrolysis and fermentation process for the production of ethanol from biomass during FY 1997. The process generated a lignin product that should be supplied for this lignin processing project as is reasonable representative of an eventual commercial product as to moisture content and chemical composition. This task will determine the physical/chemical characteristics of the lignin obtained from operation at the ethanol PDU. If suitable, this material will be supplied as possible to this testing program throughout the lifetime of the project, subject to availability. Alternately, Kraft lignin and aquasolve lignin will be used for testing as appropriate. NREL will provide the ethanol process lignin analysis results, and supply the lignin coproduct as available starting in third quarter FY 1997 and continuing as possible during the project lifetime.

*6.5.8.5 Exploratory work on a novel jet reactor for depolymerization**

The BCD process concept proven by Prof. Shabtai's group at the microautoclave level, requires scale up to confirm its technical feasibility. The large autoclave work proposed in Task 3 will be a systematic step in this direction. Prof Shabtai has indicated in his proposal that the Univ. of Utah has continuous flow reactor facilities that could be used for this purpose. Such equipment is rather traditional and is going to be very difficult to make it economically operational at the low flow rates commercially envisaged (up to 1500 tons/day of input lignin). In fact the technology proposed by Prof. Shabtai is borrowed from coal liquefaction which aimed at huge processing plants of > 10000 tons/day of coal. Lignin cannot be conceived at these large capacities. The project needs a better technology more adapted to the "small scale concept".

Ongoing work at NREL on the development of a new concept, the jet reactor, could be of great interest for the lignin depolymerization step. The engineering concept behind the jet reactor is that bond rupture can be accomplished with short reaction times in the presence of intense cavitational or sonic fields that will induce activation of specific molecular linkages. It is proposed that a series of runs should be conducted to determine the suitability of the jet reactor approach to the depolymerization of lignin using the conditions derived from Prof. Shabtai's work. This will be done using existing NREL jet reactor facilities at flow rates of about 5 kg/h of lignin. This work will be conducted during the period of FY1997 to mid-FY 1998.

*6.5.8.6 Independent analytical characterization of the tar from the BCD step.**

Notwithstanding the fact that the tar produced by Prof. Shabtai's group will be analyzed at the U. of Utah and that any product derived from work carried out at Sandia will also be analyzed by Sandia researchers, complementary analyses need to be carried out for independent validation purposes.

In particular analyses of the methoxy and hydroxy groups present in the tar and the molecular weight distribution of the oligomers are needed to understand the potential of the tar for added value chemicals.

Standardized analyses of the products from the HPR + RH and E + SRH steps ought to be made by a third party. They may include simulated distillation or the ASTM distillation method for which a minimum quantity of product is needed. Spectroscopic analyses, MBMS and nmr, will be made to complement the chromatography results provided by the U. of Utah and Sandia. NREL has all the analytical tools needed to carry out this work which will support Tasks 2, 3 & 5 over a period of two years (10/96-10/98).

*6.5.8.7 Establishment of a detailed process flow diagram for BCD and HPR + RH steps.**

Based on the material balances generated during the 1994 - 96 effort by Prof. Shabtai's group, a process flow diagram (PFD) for the BCD step will be generated. Energy balances will be estimated. Recoveries of the base and the alcohol used in the BCD step will also be estimated and adjusted with new data from the forthcoming experimentation. For the HPR + RH steps, based on the material balances generated during the 1994- 96 effort by Prof. Shabtai's group, a PFD will be generated. Energy balances will be estimated. Hydrogen consumption will be included based on either accurate material balances or estimates. Finally, recoveries and regeneration of the catalysts used in the HPR and RH steps will be estimated and adjusted from the forthcoming experimentation. As there is existing data at present, this work will be started soon after the initiation of the follow-on contract with U. of Utah, and will be completed in 2-3 months.

*6.5.8.8 Establishment of a detailed process flow diagram for etherification (E) + SRH steps.**

The etherification (E) + SRH steps represent new experimentation proposed by Prof. Shabtai for 1996-98. No existing data is available as yet. The PFD will be developed in the second fiscal year of the project, that is in 1997-98 when data and material balances will be generated by Prof. Shabtai's group. As there is no existing data at present, this work will start soon after the beginning of 1998, and will be completed in 2-3 months. Additionally, the PFD will be adjusted periodically with the new data generated from Tasks 2 and 3. As with Task 7, this work will be carried out by NREL.

*6.5.8.9 Identification of high value added products from lignin depolymerization/upgrading**

In an effort to better understand the "lignin-derived" markets, a study will be initiated to identify potential products and co-products that could enhance the economics of any lignin upgrading process. Fuel additives, high grade gasoline, chemicals and polymeric materials from lignin will be inventoried and categorized as per possible markets.

*6.5.8.10 Economic estimates for the different products.**

A preliminary economic estimate of production costs will be made for each of the different process steps. Capital and operating costs will be detailed as a function of plant site in the range comprised between 100 and 1500 tons of lignin per day. Sensitivity analyses will be conducted as a function of lignin costs, capital costs and operating costs. As well the sensitivity of yields, recovery of chemicals, and hydrogen consumption on the product cost will be determined. This task will be subcontracted out to a specialized firm familiar with this type of economic studies. It is anticipated that the work will begin in 1998 and be complete in three months.

*6.5.8.11 Scale-up of jet or other reactor for depolymerization**

It is anticipated that the jet reactor or similar continuous reactor will have been successfully tested at the pilot scale. The previous task results as well as other commercial reactors capable of meeting the necessary BCD/HPR etc. conditions will be used to design a scaled-up reactor capable of converting 50-100 wet tons per day of a biomass ethanol plant-derived lignin product. This task will include design, construction and shake-down testing of the reactor. The location will be in close conjunction with a demonstration biomass to ethanol plant operating either on biomass wastes or agriculture residues as outlined in the previous parts of this MYTP. The design, construction and testing will be completed in a joint project with NREL and Sandia National Laboratory during FY 1998.

*6.5.8.12 Demonstration testing of the lignin depolymerization reactor**

The lignin depolymerization reactor will be demonstrated at the 50-100 wet TPD scale in association with an on-going biomass ethanol Engineering Demonstration Unit (EDU) described in this MYTP. This demonstration will aim at continuous processing of the wet (50% moisture) lignin cake coming from the anticipated 5-10 million gallon per year plant that will be producing lignin at approximately 60 to 120 wet tons per day. This demonstration is anticipated to start in FY 1999 and continue throughout FY 2000 to obtain process data needed for eventual full scale-up of the BCD and follow-on process steps needed to produce a higher value lignin product at commercial scale

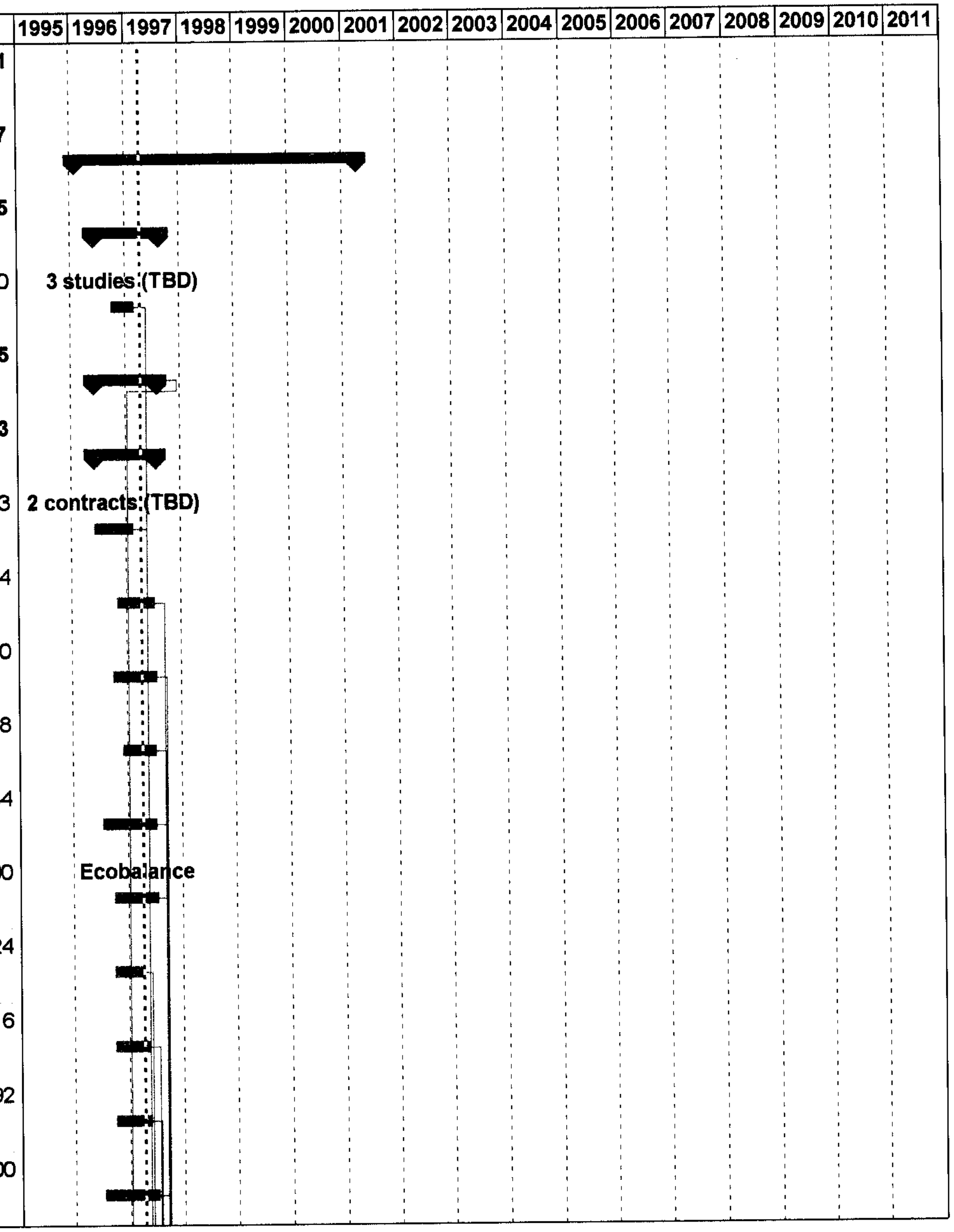
Figure 9: Ethanol Multi-Year Technical Plan (Bioethanol Program Plan v24)

Shown in the next 29 pages

Ethanol Multi-Year Technical Plan

Bioethanol Program Plan v24

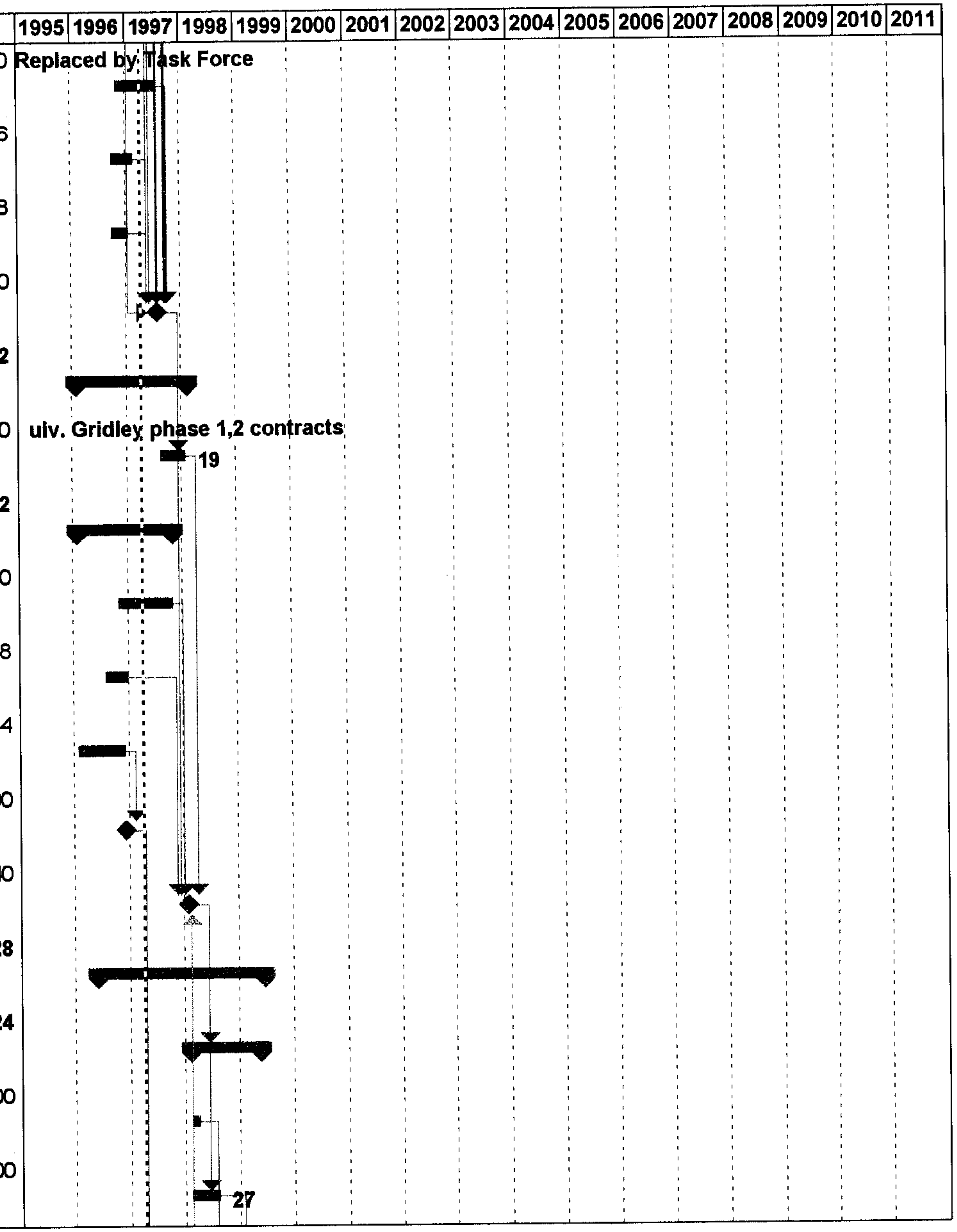
ID	WBS	Task Name	Fixed Cost	Total Cost
	0	**Bioethanol Program Plan v24**	**$0.00**	**$82,927,567.91**
1	1	**Commercially demonstrate waste biomass to ethanol technology**	**$0.00**	**$9,333,337.67**
2	1.1	**Preliminary Feasibility Studies**	**$0.00**	**$1,563,964.95**
3	1.1.1	Conduct New Preliminary Feasibility Studies (supported by limited laboratory work)	$300,000.00	$575,536.80
4	1.1.2	**Complete Existing Preliminary Feasibility Studies (supported by limited laboratory work)**	**$0.00**	**$960,909.75**
5	1.1.2.1	**Near term softwood opportunities**	**$0.00**	**$611,467.43**
6	1.1.2.1.1	Quincy Library Group Feasibility Study (softwood)	$225,000.00	$252,561.03
7	1.1.2.1.2	Colorado "Pine Zone" Feasibility Study (softwood)	$0.00	$41,912.64
8	1.1.2.1.3	2 contracts (TBD)	$35,000.00	$86,861.60
9	1.1.2.1.4	PALCO and LP Feasibility Studies (softwood)	$0.00	$14,676.48
10	1.1.2.1.5	IBI CRADA (softwood)	$0.00	$44,029.44
11	1.1.2.1.6	CARB Bioethanol Life Cycle Analysis (softwood)	$90,000.00	$164,088.00
12	1.1.2.1.7	Washington State Energy Office Pulp Mill Feasibility Study (softwood)	$0.00	$7,338.24
13	1.1.2.2	ACE Feasibility Study (CRP grass)	$120,000.00	$130,478.16
14	1.1.2.3	Iowa Feasibility Study (CRP grass)	$0.00	$55,177.92
15	1.1.2.4	Delta-T CRADA (feedstock to be determined)	$0.00	$45,864.00



Ethanol Multi-Year Technical Plan

Bioethanol Program Plan v24

ID	WBS	Task Name	Fixed Cost	Total Cost
16	1.1.2.5	Cellulase Partnership with logen	$100,000.00	$100,000.00
17	1.1.2.6	Quaker Oats Chemicals/Manildra Feasibility Study (other feedstock)	$0.00	$8,890.56
18	1.1.2.7	Pure Vision Feasibility Study (other feedstock)	$0.00	$9,031.68
19	1.1.3	Select Partners for Final Feasibility Studies (apply Final Feasibility Study selection criteria)	$0.00	$27,518.40
20	**1.2**	**Final Feasibility Studies**	**$0.00**	**$3,895,112.32**
21	1.2.1	Conduct New Final Feasibility Studies (supported by laboratory work)	$2,500,000.00	$3,312,851.20
22	**1.2.2**	**Complete Existing Final Feasibility Studies (supported by laboratory work)**	**$0.00**	**$554,742.72**
23	1.2.2.1	Coors CRADA Phase 2 (grain milling residue)	$0.00	$238,492.80
24	1.2.2.2	New Energy CRADA (grain milling residue)	$0.00	$60,540.48
25	1.2.2.3	Gridley Project Phase 1 (rice straw)	$0.00	$255,709.44
26	1.2.2.4	Gridley Phase 2 Go/No-go Decision	$0.00	$0.00
27	1.2.3	Select Partners for Business Plan Development (apply demonstration partner selection criteria)	$0.00	$27,518.40
28	**1.3**	**Business Plans**	**$0.00**	**$1,557,433.28**
29	**1.3.1**	**Conduct New Business Plans**	**$0.00**	**$944,690.24**
30	1.3.1.1	Negotiate Legal Arrangements with Partners	$0.00	$56,448.00
31	1.3.1.2	Establish Feedstock/Product Contracts and Site Commitments	$0.00	$45,864.00



Ethanol Multi-Year Technical Plan

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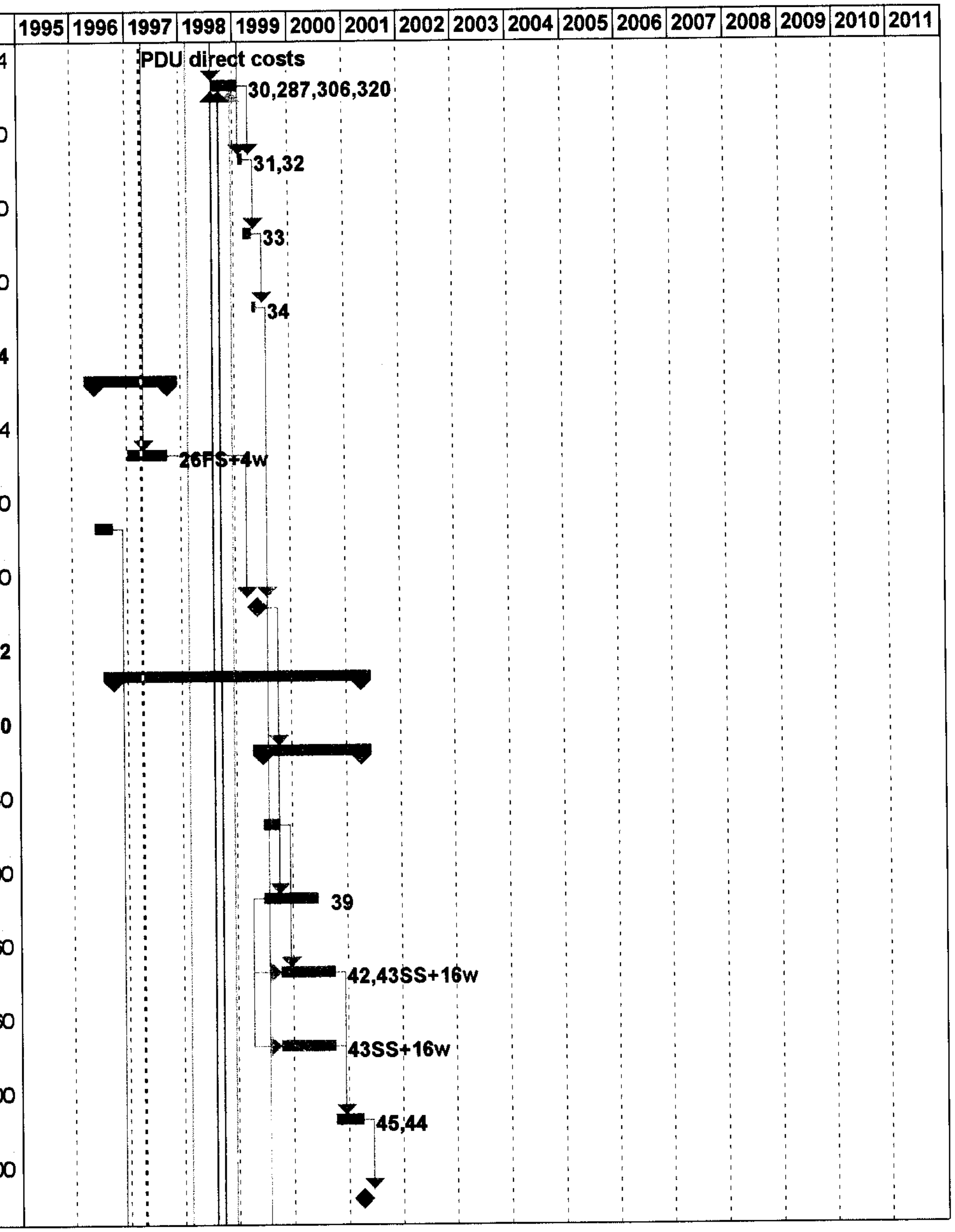
ID	WBS	Task Name	Fixed Cost	Total Cost
32	1.3.1.3	Conduct PDU Testing and Data Analysis	$200,000.00	$757,706.24
33	1.3.1.4	Re-evaluate Process Design and Cost Estimate	$0.00	$14,112.00
34	1.3.1.5	Negotiate License Agreements and Performance Guarantees	$0.00	$56,448.00
35	1.3.1.6	Issue New Business Plans	$0.00	$14,112.00
36	**1.3.2**	**Complete Existing Business Plans**	**$0.00**	**$557,706.24**
37	1.3.2.1	Gridley Phase 2 - issue business plan	$0.00	$557,706.24
38	1.3.2.2	Amoco CRADA Phase 3	$0.00	$0.00
39	1.3.3	Select Partners for Demonstration Plant Development	$0.00	$55,036.80
40	**1.4**	**Demonstration Plants**	**$0.00**	**$2,316,827.12**
41	**1.4.1**	**Conduct New Demonstration Plant Efforts**	**$0.00**	**$2,299,928.00**
42	1.4.1.1	Finance Facility	$0.00	$5,644.80
43	1.4.1.2	Conduct Detailed Design	$100,000.00	$191,728.00
44	1.4.1.3	Obtain Permits	$20,000.00	$38,345.60
45	1.4.1.4	Construct Facility	$2,000,000.00	$2,018,345.60
46	1.4.1.5	Start Up Facility by Year 2000	$0.00	$45,864.00
47	1.4.1.6	Commercial Operation	$0.00	$0.00



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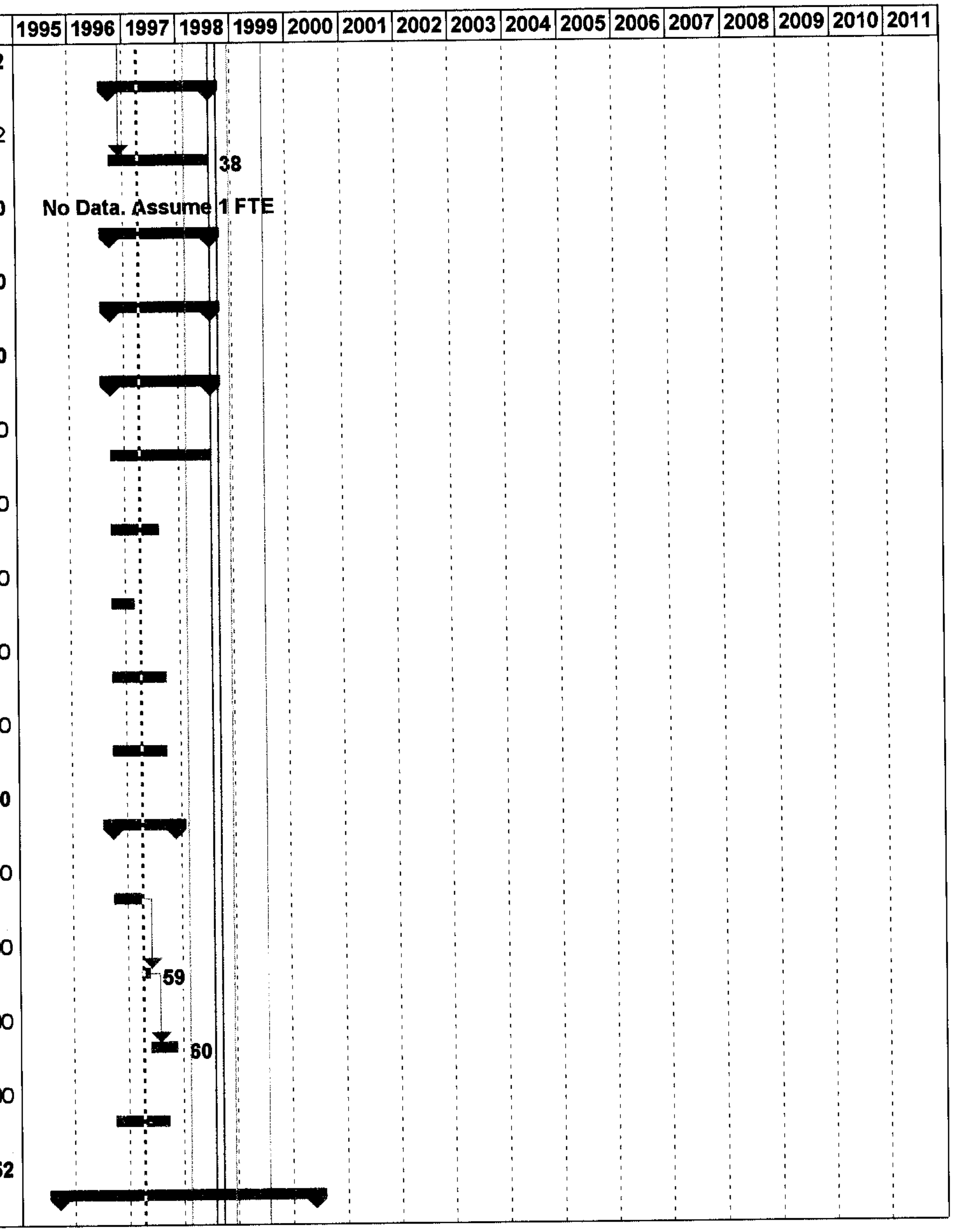
ID	WBS	Task Name	Fixed Cost	Total Cost
48	**1.4.2**	**Complete Existing Demonstration Plant Efforts**	**$0.00**	**$16,899.12**
49	1.4.2.1	Amoco CRADA Phase 4 - Final Report on Demonstration Plant Due	$0.00	$16,899.12
50	**2**	**Develop and Maintain PDT Capabilities and Data Bases to Support Year 2000 Goal**	**$0.00**	**$538,688.00**
51	**2.1**	**PDT Tools, Data Bases and Capabilities to Conduct Feasibility/Business Plans**	**$200,000.00**	**$200,000.00**
52	**2.1.1**	**Develop Data Base for Near-Term Feedstock**	**$0.00**	**$0.00**
53	2.1.1.1	Develop Forest Residue GIS Database	$0.00	$0.00
54	2.1.1.2	Develop Saw & Pulp Mill GIS Database	$0.00	$0.00
55	2.1.1.3	Montana State Wood Waste Assessment	$0.00	$0.00
56	2.1.2	Maintain PDT Engineering/Economic Analysis Models	$0.00	$0.00
57	2.2	Develop Data Base for Sources of Funding to Partners	$0.00	$0.00
58	**3**	**Establish Partnerships for Long-Term Research**	**$0.00**	**$0.00**
59	3.1	Determine Key Long-Term Research Objectives	$0.00	$0.00
60	3.2	Determine Who Should Conduct Research to Achieve Long-Term Objectives	$0.00	$0.00
61	3.3	Establish Partnerships with Non-NREL Entities	$0.00	$0.00
62	4	Coordinate With Federal, State, Local & Private Organizations to Support Ethanol Utilization	$0.00	$0.00
63	**5**	**Develop Switchgrass Partnerships for Ethanol Production**	**$0.00**	**$2,523,285.52**



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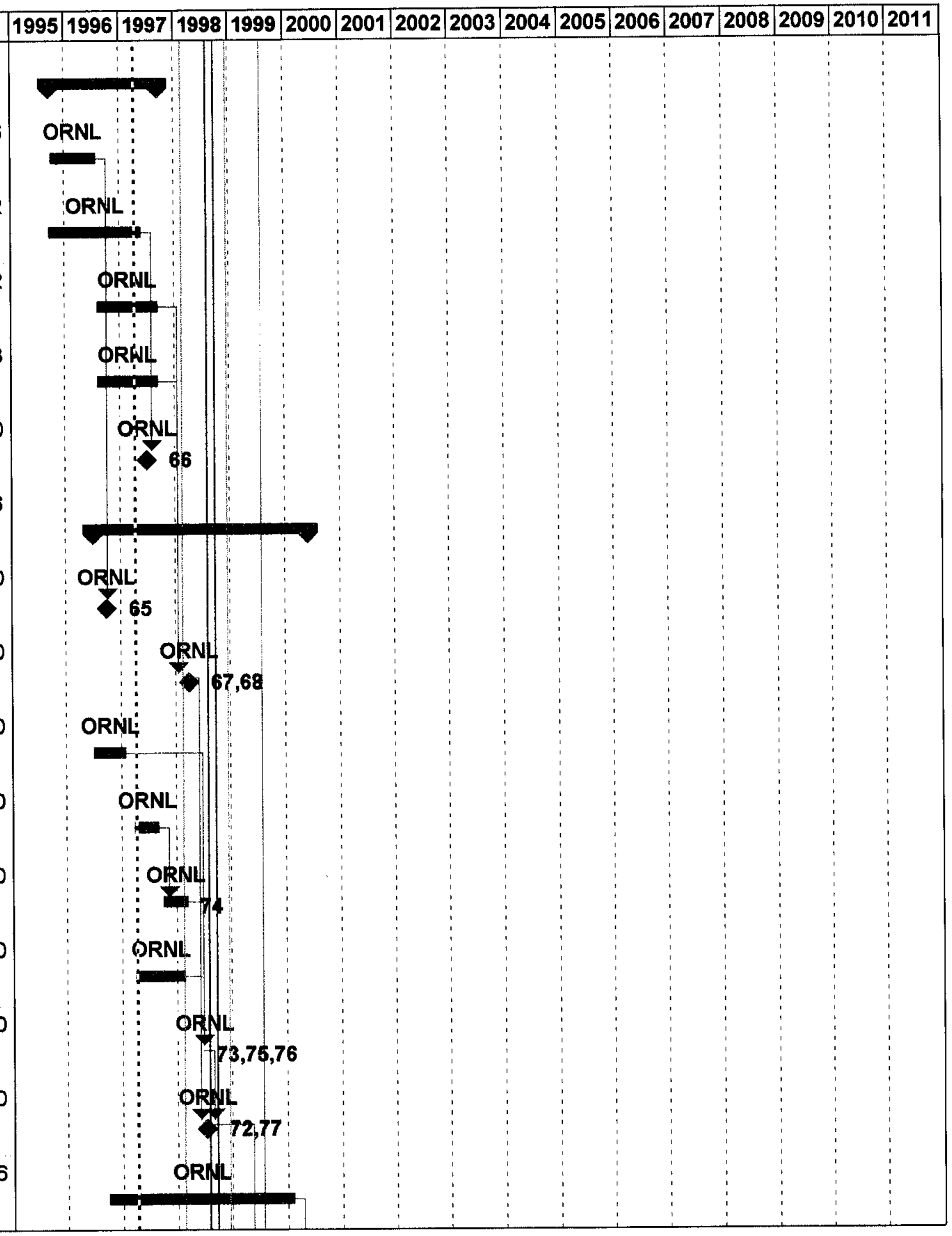
ID	WBS	Task Name	Fixed Cost	Total Cost
64	**5.1**	**Identify potential locations for crop supplies at $42/dry ton**	**$0.00**	**$607,027.68**
65	5.1.1	Complete crop economic baselines at national and regional levels (4.01)	$0.00	$107,674.56
66	5.1.2	Complete integrated GIS analysis in selected states (4.02-.05)	$0.00	$140,026.32
67	5.1.3	Complete Integrated GIS analysis of potential in 14 states (4.02-05)	$0.00	$92,398.32
68	5.1.4	Complete preliminary waste and feedstock supply database for all of US (4.06)	$0.00	$266,928.48
69	5.1.5	Recommend locations for focused R&D, scale-up and market analysis (4.02-05)	$0.00	$0.00
70	**5.2**	**Assist feasibility studies with integrated analysis products**	**$0.00**	**$286,367.76**
71	5.2.1	Provide integrated crop economic models for developers & analysts (4.01)	$0.00	$0.00
72	5.2.2	Provide results of GIS model runs to states, developers & analysts (4.02-.5)	$0.00	$0.00
73	5.2.3	Provide feedstock supply curves for ethanol market penetration model (4.09)	$0.00	$79,909.20
74	5.2.4	Collaborate with USDA on putting switchgrass & SRWC in model (4.08)	$0.00	$32,457.60
75	5.2.5	Use USDA models for improving feedstock supply curves (4.08)	$0.00	$16,934.40
76	5.2.6	Integrate cost & production risks in farmer decision making models (4.10)	$0.00	$33,163.20
77	5.2.7	Publish crop supply models and scenario results (4.01&.09)	$0.00	$0.00
78	5.2.8	Recommend locations for preliminary feasibility studies (5.0)	$0.00	$0.00
79	5.2.9	Update crop economic info as new data becomes available (4.01)	$0.00	$123,903.36



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ID	WBS	Task Name	Fixed Cost	Total Cost	Gantt (1995–2011)
80	5.2.10	Release updated crop economic models for developers & analysts (4.01)	$0.00	$0.00	ORNL 79
81	**5.3**	**Expand switchgrass supply system expertise & interest**	**$0.00**	**$1,629,890.08**	
82	5.3.1	Summarize and publish results of first 5 yrs SG R&D	$0.00	$22,050.00	ORNL
83	**5.3.2**	**Expand number and scale of switchgrass testing locations**	**$0.00**	**$388,962.00**	
84	5.3.2.1	Farmer participation in Chariton Valley, Iowa secured	$0.00	$183,456.00	ORNL
85	5.3.2.2	Renegotiate Univ. contracts to include scale-ups & satelites (2.0)	$0.00	$22,050.00	ORNL
86	5.3.2.3	Negotiate extending variety testing & breeding to Wisconsin(2.07)	$0.00	$91,728.00	onsin via ORNL (not Biofuels funded)
87	5.3.2.4	USDA Plant Materials Center Participation Secured	$0.00	$91,728.00	ORNL
88	**5.3.3**	**Predict switchgrass market potential for feasibility studies**	**$0.00**	**$325,000.00**	
89	5.3.3.1	Link ISU economics experts with Chariton RC&D (5.05)	$115,000.00	$115,000.00	xed costs for Iowa State Econ. via ORNL
90	5.3.3.2	Link ag economics expertise with other scale-up sites (5.03)	$210,000.00	$210,000.00	ORNL
91	5.3.3.3	Provide economic info for final feasibility studies	$0.00	$0.00	ORNL 89,90
92	**5.3.4**	**Predict environmental effects of switchgrass supply systems**	**$0.00**	**$342,216.00**	
93	5.3.4.1	Develop models for national/regional environmental effects analysis (4.0)	$0.00	$138,297.60	ORNL
94	5.3.4.2	Model & predict regional level water quality effects (4.0)	$0.00	$0.00	ORNL 93
95	5.3.4.3	Collect & evaluate info on soil nutrient and carbon changes(2.0)	$0.00	$130,536.00	ORNL

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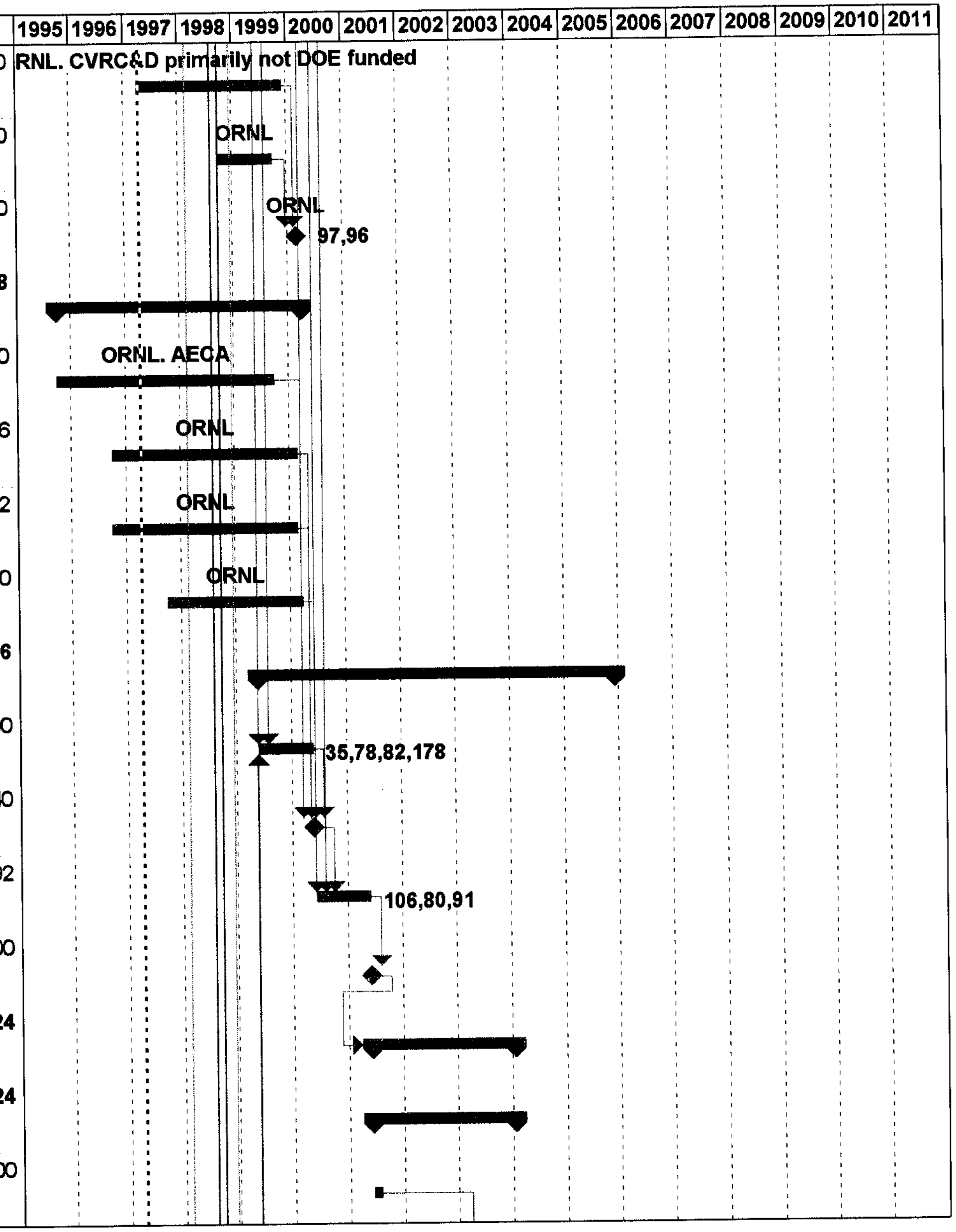
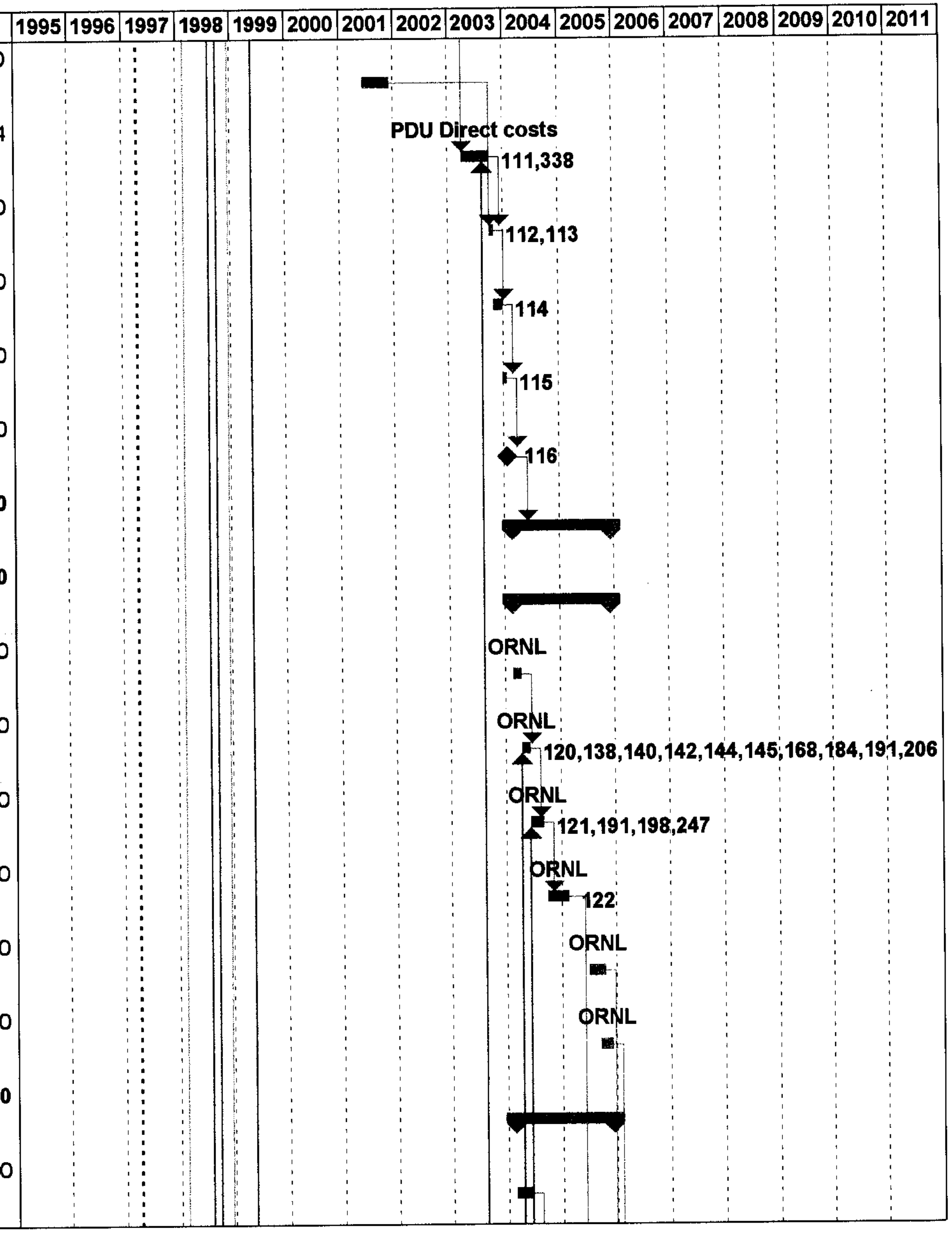
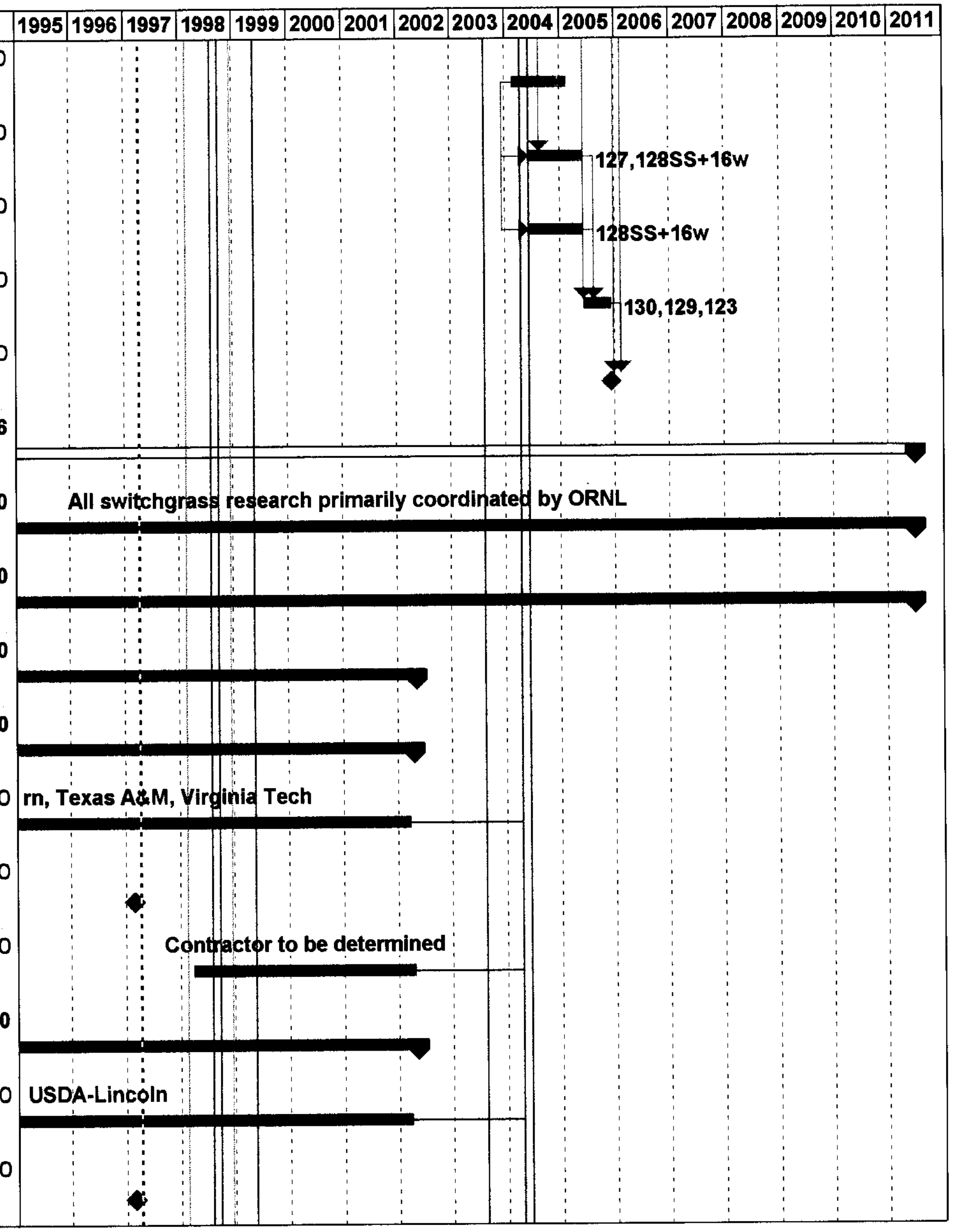
ID	WBS	Task Name	Fixed Cost	Total Cost
96	5.3.4.4	Model erosion and water quality effects in Iowa (CVRC&D)	$0.00	$0.00
97	5.3.4.5	Compare SG & alt. crop environmental effects from available data	$0.00	$73,382.40
98	5.3.4.6	Publish preliminary predictions of env. effects of switchgrass (3.4.1)	$0.00	$0.00
99	**5.3.5**	**Stimulate producer interest in business plan development**	**$0.00**	**$551,662.08**
100	5.3.5.1	Develop farmer oriented news outlets, hold news broadcasts (5.0, 5.02)	$60,000.00	$133,735.20
101	5.3.5.2	Conduct field days and workshops for farmers & developers (5.0, 5.02)	$0.00	$62,868.96
102	5.3.5.3	Develop networks with farmers and developers (5.0)	$0.00	$125,737.92
103	5.3.5.4	Educate public, developers, policy makers on environmental benefits (3.0,5.0,6.0)	$0.00	$229,320.00
104	**6**	**Commercially demonstrate switchgrass to ethanol technology**	**$0.00**	**$5,404,885.76**
105	6.1	Preliminary feasibility studies	$300,000.00	$575,184.00
106	6.2	Select partners for final feasibility studies	$0.00	$27,518.40
107	6.3	Final feasibility studies	$1,000,000.00	$1,288,025.92
108	6.4	Select partners for business plan development	$0.00	$7,056.00
109	**6.5**	**Business Plans**	**$0.00**	**$944,690.24**
110	**6.5.1**	**Conduct New Business Plans**	**$0.00**	**$944,690.24**
111	6.5.1.1	Negotiate Legal Arrangements with Partners	$0.00	$56,448.00



ID	WBS	Task Name	Fixed Cost	Total Cost
112	6.5.1.2	Establish Feedstock/Product Contracts and Site Commitments	$0.00	$45,864.00
113	6.5.1.3	Conduct PDU Testing and Data Analysis	$200,000.00	$757,706.24
114	6.5.1.4	Re-evaluate Process Design and Cost Estimate	$0.00	$14,112.00
115	6.5.1.5	Negotiate License Agreements and Performance Guarantees	$0.00	$56,448.00
116	6.5.1.6	Issue New Business Plans	$0.00	$14,112.00
117	6.6	Select Partners for Demonstration Plant Development	$0.00	$55,036.80
118	**6.7**	**Demonstration Plants**	**$0.00**	**$2,507,374.40**
119	**6.7.1**	**Agricultural Production**	**$0.00**	**$38,102.40**
120	6.7.1.1	Establish Feedstock Supply Contracts & Financing	$0.00	$14,112.00
121	6.7.1.2	Fall site preparation & secure seed	$0.00	$2,822.40
122	6.7.1.3	Spring site preparation & planting	$0.00	$4,233.60
123	6.7.1.4	First year harvest (stored for start-up runs)	$0.00	$7,056.00
124	6.7.1.5	Evaluate supply & contract for wastes if necessary	$0.00	$5,644.80
125	6.7.1.6	Second year harvest;pre-commercial start-up	$0.00	$4,233.60
126	**6.7.2**	**Conduct New Demonstration Plant Efforts**	**$0.00**	**$2,469,272.00**
127	6.7.2.1	Finance Facility	$0.00	$28,224.00



ID	WBS	Task Name	Fixed Cost	Total Cost
128	6.7.2.2	Conduct Detailed Design	$100,000.00	$191,728.00
129	6.7.2.3	Obtain Permits	$20,000.00	$111,728.00
130	6.7.2.4	Construct Facility	$2,000,000.00	$2,091,728.00
131	6.7.2.5	Start Up Facility by Year 2005	$0.00	$45,864.00
132	6.7.2.6	Commercial Operation	$0.00	$0.00
133	**7**	**Core Technology Development**	**$0.00**	**$65,127,370.96**
134	**7.1**	**Switchgrass Feedstock Production Technology**	**$0.00**	**$21,840,082.00**
135	**7.1.1**	**Support Switchgrass Crop Development Centers in at least 4 regions**	**$0.00**	**$18,482,338.00**
136	**7.1.1.1**	**Identify best varieties and yield potential**	**$0.00**	**$2,290,000.00**
137	**7.1.1.1.1**	**Screen for best varieties in South & Mid-Atlantic States**	**$0.00**	**$1,640,000.00**
138	7.1.1.1.1.1	Screen available varieties at 19 sites for high& sustained yield (2.02,2.03,2.04,)	$600,000.00	$600,000.00
139	7.1.1.1.1.2	Recommend best varieties for first scale-up & breeding (2.02,2.03,2.04))	$0.00	$0.00
140	7.1.1.1.1.3	Expand variety screening to 13 other states	$1,040,000.00	$1,040,000.00
141	**7.1.1.1.2**	**Screen for best varieties & locations in NC & NE/L states**	**$0.00**	**$650,000.00**
142	7.1.1.1.2.1	Screen available varieties in Nebraska for high & sustained yield (2.07)	$100,000.00	$100,000.00
143	7.1.1.1.2.2	Recommend best varieties for first scale-up & breeding (2.07))	$0.00	$0.00



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ID	WBS	Task Name	Fixed Cost	Total Cost	1995–2011
144	7.1.1.1.2.3	Screen available varieties in Wisconsin for high & sustained yield (2.07)	$50,000.00	$50,000.00	USDA Wisconsin
145	7.1.1.1.2.4	Expand variety screening to 10 other states	$500,000.00	$500,000.00	CVRC&D and a contractor to be determined
146	**7.1.1.2**	**Optimize culture to improve yields & benefit environment**	**$0.00**	**$10,119,698.40**	
147	**7.1.1.2.1**	**Test culture effects in Southern & Mid-Atl. experiments 1-10 acre**	**$0.00**	**$4,651,728.00**	
148	7.1.1.2.1.1	Identify establishment & fertilizer requirements (2.02,2.03,2.04)	$900,000.00	$900,000.00	and Virginia Tech
149	7.1.1.2.1.2	Provide preliminary crop mgm guidelines for R&D scale-ups (2.02,2.03,2.04)	$0.00	$0.00	
150	7.1.1.2.1.3	Identify nutrient factors affecting yield & quality (2.02, 2.03, 2.04)	$360,000.00	$360,000.00	Auburn, Texas A&M, Virginia Tech
151	7.1.1.2.1.4	Identify harvest factors affecting yield & quality (2.02, 2.03, 2.04)	$180,000.00	$180,000.00	Auburn, Texas A&M, Virginia Tech
152	7.1.1.2.1.5	Provide improved crop mgm guidelines for feasibility studies (2.02,2.03, 2.04)	$0.00	$0.00	
153	7.1.1.2.1.6	Use data to improve econ., env, and supply models	$0.00	$91,728.00	150,151
154	7.1.1.2.1.7	Repeat above in 13 other states with extension links	$3,120,000.00	$3,120,000.00	TBD
155	**7.1.1.2.2**	**Test culture effects in NC experiments 1-10 acre**	**$0.00**	**$3,091,728.00**	
156	7.1.1.2.2.1	Identify establishment & fertilizer requirements (2.07)	$200,000.00	$200,000.00	coln
157	7.1.1.2.2.2	Provide preliminary crop mgm guidelines to growers for scale-ups (2.07)	$0.00	$0.00	
158	7.1.1.2.2.3	Identify nutrient factors affecting yield & quality (2.08)	$0.00	$0.00	CVRC%D. No DOE cost
159	7.1.1.2.2.4	Identify harvest factors affecting yield and quality (2.08)	$0.00	$0.00	CVRC&D No DOE cost

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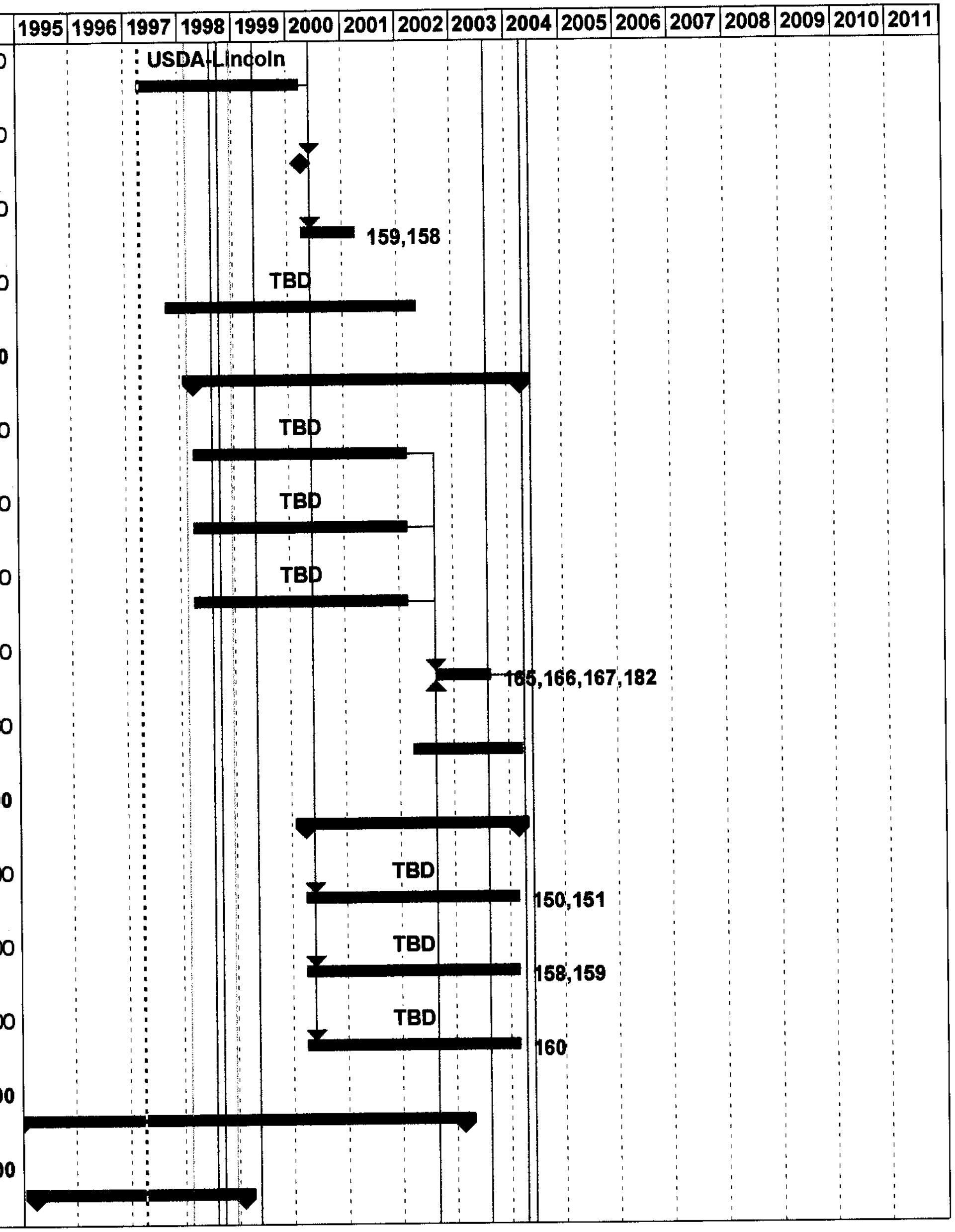
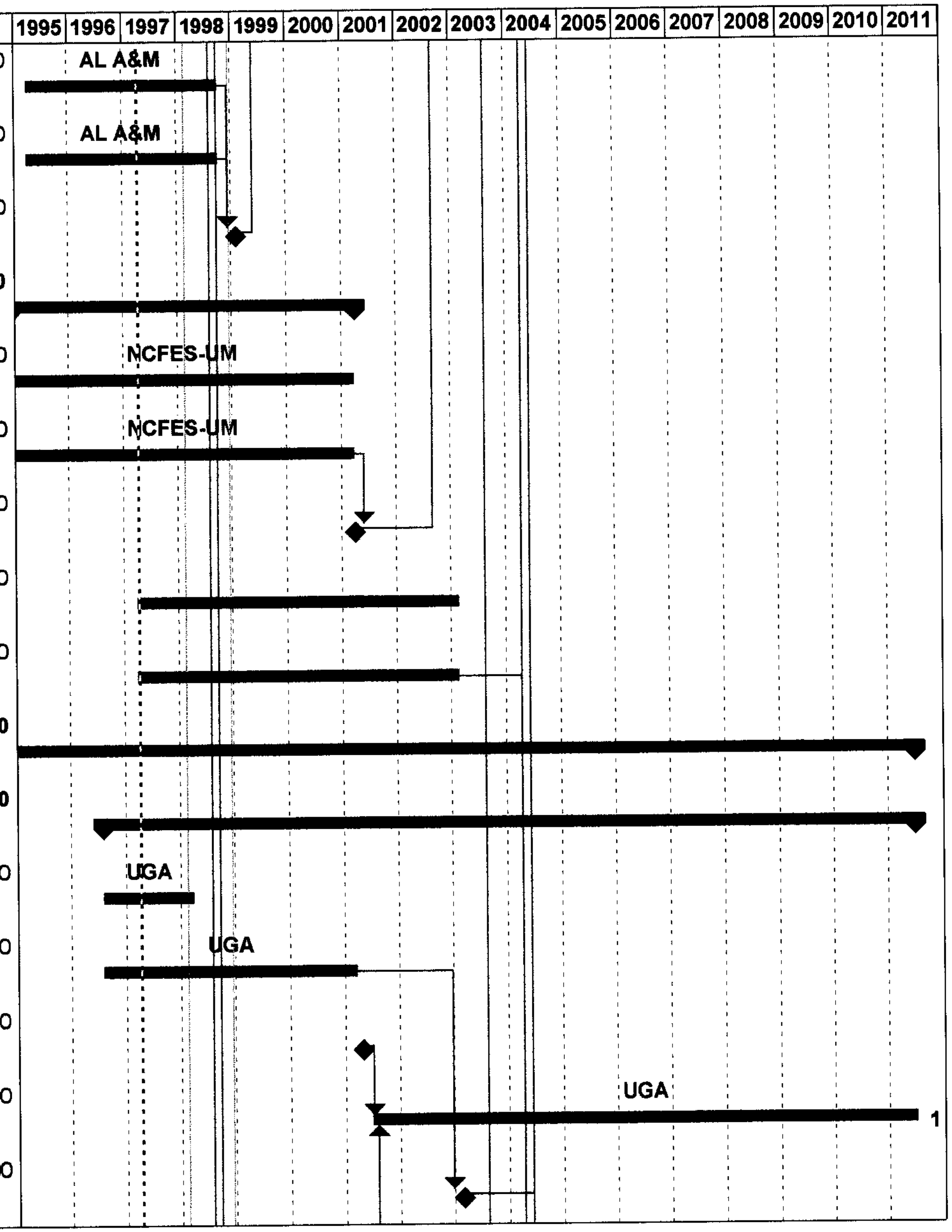
ID	WBS	Task Name	Fixed Cost	Total Cost
160	7.1.1.2.2.5	Develop information necessary to register new herbicides	$100,000.00	$100,000.00
161	7.1.1.2.2.6	Provide improved crop mgm guidelines for feasibility studies (2.08)	$0.00	$0.00
162	7.1.1.2.2.7	Use data to improve econ., env., and supply models	$0.00	$91,728.00
163	7.1.1.2.2.8	Repeat above in 13 other states with extension links	$2,700,000.00	$2,700,000.00
164	**7.1.1.2.3**	**Improve culture through understanding mechanisms**	**$0.00**	**$1,976,242.40**
165	7.1.1.2.3.1	Develop mechanistic understanding of yield response to soils, climate, etc.	$800,000.00	$800,000.00
166	7.1.1.2.3.2	Develop mechanistic understanding of responses to mgm options	$800,000.00	$800,000.00
167	7.1.1.2.3.3	Develop information on value of ash & wastes as soil amendments	$100,000.00	$100,000.00
168	7.1.1.2.3.4	Use information to improve culture guidelines	$0.00	$92,080.80
169	7.1.1.2.3.5	Use information to improve national feedstock supply models	$0.00	$184,161.60
170	**7.1.1.2.4**	**Adapt culture to potential locations for commercial demos**	**$0.00**	**$400,000.00**
171	7.1.1.2.4.1	Identify best establishment techniques for locations	$160,000.00	$160,000.00
172	7.1.1.2.4.2	Test range of fertilizer levels & methods of appl.	$160,000.00	$160,000.00
173	7.1.1.2.4.3	Test herbicide types, rates, & appl. methods	$80,000.00	$80,000.00
174	**7.1.1.3**	**Evaluate environmental effects of culture techniques at few sites**	**$0.00**	**$1,442,430.00**
175	**7.1.1.3.1**	**Develop SE management options for environmentally sound approaches**	**$0.00**	**$300,000.00**



ID	WBS	Task Name	Fixed Cost	Total Cost
176	7.1.1.3.1.1	Evaluate surface & subsurface water quality as function of management (3.2.2)	$150,000.00	$150,000.00
177	7.1.1.3.1.2	Evaluate soil quality responses as function of management & crop (3.2.2)	$150,000.00	$150,000.00
178	7.1.1.3.1.3	Provide site mgm/env guidelines to growers & EPA	$0.00	$0.00
179	**7.1.1.3.2**	**Develop NC site management options for environmental soundness**	**$0.00**	**$600,000.00**
180	7.1.1.3.2.1	Evaluate subsurface water quality as function of management (3.2.1)	$300,000.00	$300,000.00
181	7.1.1.3.2.2	Evaluate soil quality responses as function of management & crop (3.2.1)	$300,000.00	$300,000.00
182	7.1.1.3.2.3	Provide site mgm/env. guidelines to growers & EPA	$0.00	$0.00
183	7.1.1.3.3	Educate multiple groups on environmental benefits	$0.00	$542,430.00
184	7.1.1.3.4	Integrate culture research results into analysis & guidelines	$0.00	$0.00
185	**7.1.1.4**	**Improve yields through breeding and testing**	**$0.00**	**$3,195,000.00**
186	**7.1.1.4.1**	**Improve SE yields through breeding & testing (2.09)**	**$0.00**	**$1,070,000.00**
187	7.1.1.4.1.1	Germplasm collection	$20,000.00	$20,000.00
188	7.1.1.4.1.2	Round 1 breeding, yield screening & regional testing	$450,000.00	$450,000.00
189	7.1.1.4.1.3	Evaluate progress to date; modify breeding strategy	$0.00	$0.00
190	7.1.1.4.1.4	Round 2 breeding, screening, regional testing	$600,000.00	$600,000.00
191	7.1.1.4.1.5	first new biomass SE varieties released for large-scale testing	$0.00	$0.00



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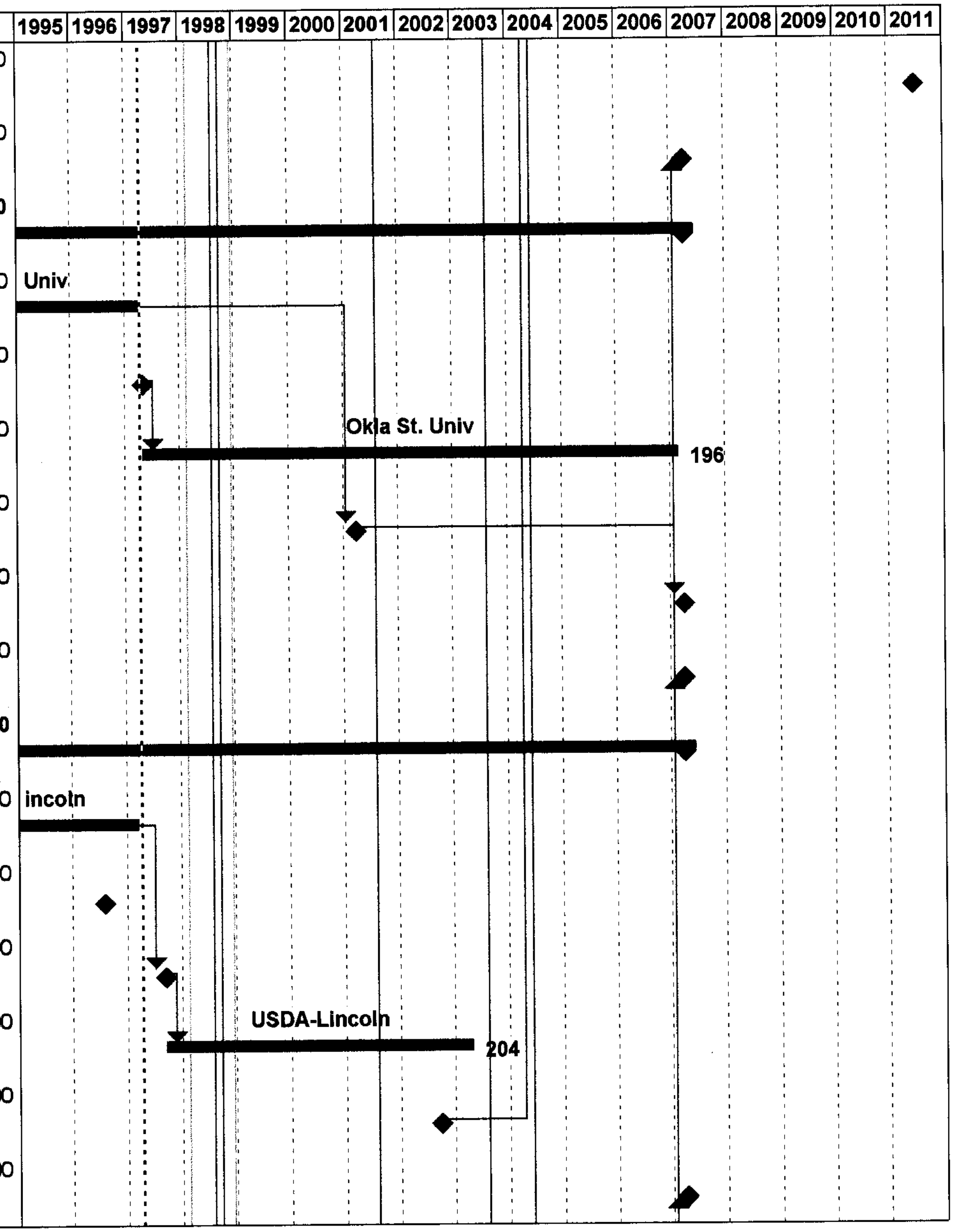
ID	WBS	Task Name	Fixed Cost	Total Cost
192	7.1.1.4.1.6	additional new varieties released to seed companies	$0.00	$0.00
193	7.1.1.4.1.7	Hand-off breeding to other agencies/private companies	$0.00	$0.00
194	**7.1.1.4.2**	**Improve SC yields through breeding & testing in SC region (2.01)**	**$0.00**	**$1,275,000.00**
195	7.1.1.4.2.1	Round 1 breeding, screening & regional testing in SC reg.	$425,000.00	$425,000.00
196	7.1.1.4.2.2	Evaluate progress; modify breeding strategy	$0.00	$0.00
197	7.1.1.4.2.3	Round 2 breeding, screening, regional testing	$850,000.00	$850,000.00
198	7.1.1.4.2.4	first new SC biomass varieties released to seed companies	$0.00	$0.00
199	7.1.1.4.2.5	additional new varieties released to seed companies	$0.00	$0.00
200	7.1.1.4.2.6	Hand-off breeding to other agencies/private companies	$0.00	$0.00
201	**7.1.1.4.3**	**Improve NC yields through breeding & testing (2.07)**	**$0.00**	**$440,000.00**
202	7.1.1.4.3.1	Round 1 breeding, biomass screening, regional testing in NC	$200,000.00	$200,000.00
203	7.1.1.4.3.2	1 new improved forage/biomass variety released in NC	$0.00	$0.00
204	7.1.1.4.3.3	Evaluate progress; modify breeding strategy	$0.00	$0.00
205	7.1.1.4.3.4	Round 2 breeding, screening, regional testing	$240,000.00	$240,000.00
206	7.1.1.4.3.5	1-2 new varieties released to seed companies	$0.00	$0.00
207	7.1.1.4.3.6	Hand-off breeding to other agencies/private companies	$0.00	$0.00



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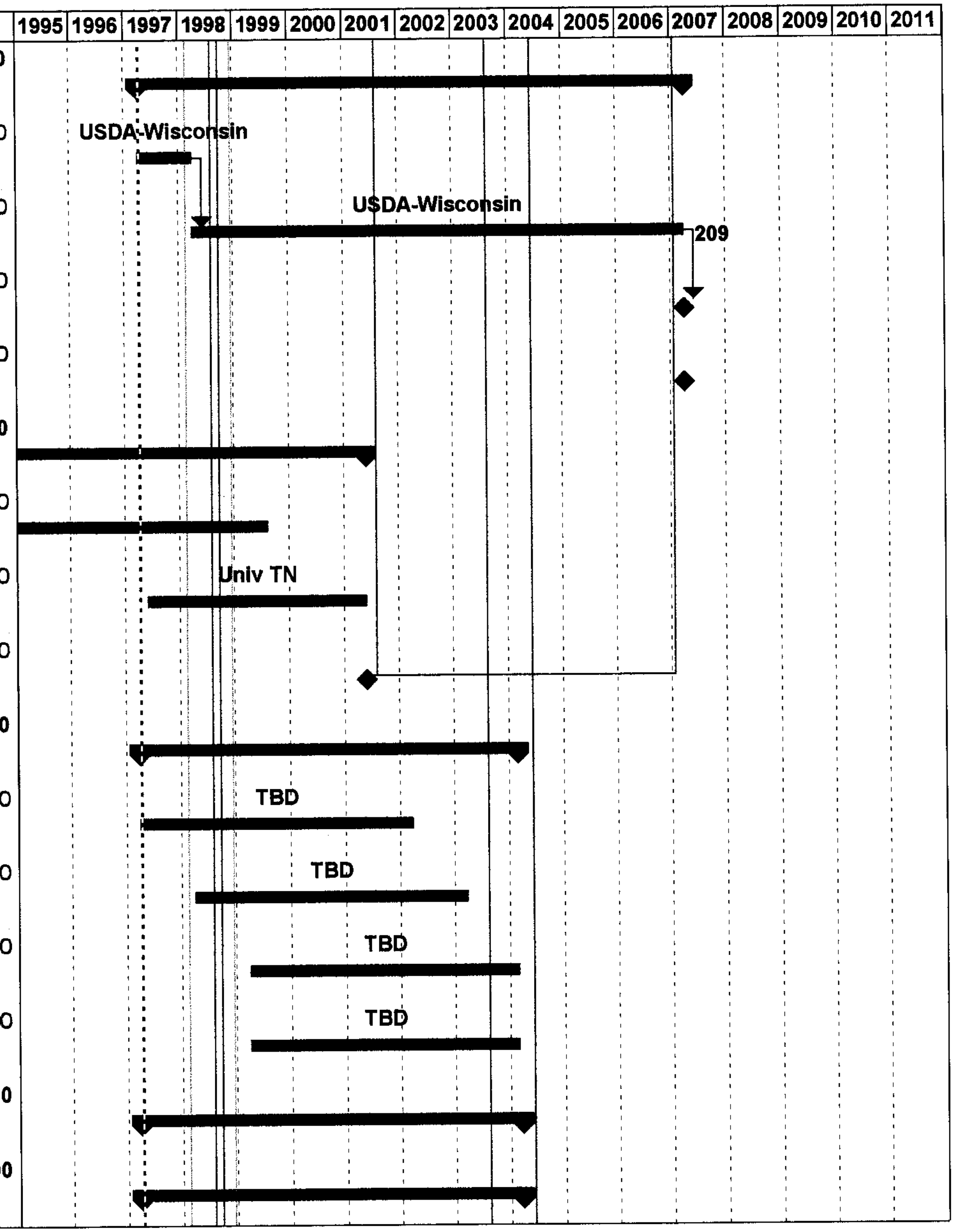
ID	WBS	Task Name	Fixed Cost	Total Cost
208	**7.1.1.4.4**	**Improve NE/Lake yields through breeding & testing (2.07)**	**$0.00**	**$410,000.00**
209	7.1.1.4.4.1	Germplasm collection	$10,000.00	$10,000.00
210	7.1.1.4.4.2	Round 1 breeding, yield screening & regional testing in NE/L	$400,000.00	$400,000.00
211	7.1.1.4.4.3	1-2 new varieties released in NE/L	$0.00	$0.00
212	7.1.1.4.4.4	Hand-off breeding to other agencies/private companies	$0.00	$0.00
213	**7.1.1.5**	**Develop physiology/biotechnology information**	**$0.00**	**$785,209.60**
214	7.1.1.5.1	Improve growth physiology understanding and links to genetics	$0.00	$505,209.60
215	7.1.1.5.2	Develop enhanced breeding techniques based on tissue cultured plants	$280,000.00	$280,000.00
216	7.1.1.5.3	Handoff information to breeding activities/private sector breeders	$0.00	$0.00
217	**7.1.1.6**	**Assure sustainable yields by addressing pathogen & pest issues**	**$0.00**	**$650,000.00**
218	7.1.1.6.1	Use Iowa scale-up to monitor pathogens and pests	$75,000.00	$75,000.00
219	7.1.1.6.2	Monitor pathogens &pests in all additional scale-ups	$150,000.00	$150,000.00
220	7.1.1.6.3	Evaluate control mechanisms for pathogens and pests if necessary	$375,000.00	$375,000.00
221	7.1.1.6.4	Include pathogen/pest resistance in breeding efforts	$50,000.00	$50,000.00
222	**7.1.2**	**Reduce risks & expand expertise through scale-up research**	**$0.00**	**$3,357,744.00**
223	**7.1.2.1**	**Expand number and scale of switchgrass field R&D projects**	**$0.00**	**$420,000.00**



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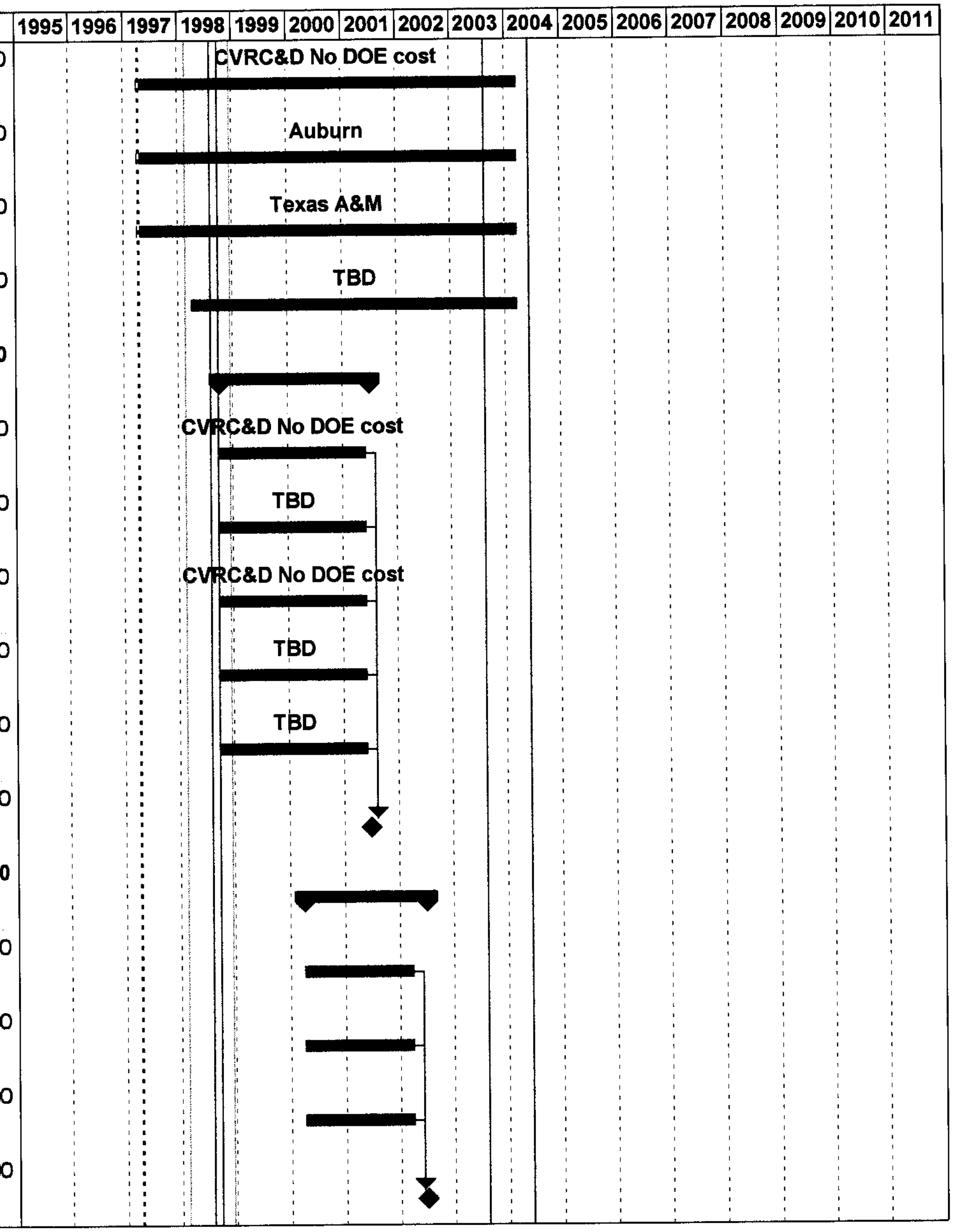
ID	WBS	Task Name	Fixed Cost	Total Cost
224	7.1.2.1.1	New plantings in Chariton Valley, Iowa (4000 acres)	$0.00	$0.00
225	7.1.2.1.2	New plantings in SC region (20-50 acres) (2.03)	$140,000.00	$140,000.00
226	7.1.2.1.3	New plantings in SE region (20-500 acres), (2.04)	$140,000.00	$140,000.00
227	7.1.2.1.4	New plantings in alternate region (20-50 acres)	$140,000.00	$140,000.00
228	**7.1.2.2**	**Improve Engineering of Switchgrass Harvest, Handling & Storage operations**	**$0.00**	**$760,000.00**
229	7.1.2.2.1	Test/modify existing large harvesters to handle higher yields (Iowa)	$0.00	$0.00
230	7.1.2.2.2	Test/modify existing small harvesters to handle higher yields	$160,000.00	$160,000.00
231	7.1.2.2.3	Identify best field storage & handling alternatives for NC	$0.00	$0.00
232	7.1.2.2.4	Identify best field storage & handling alternatives for SE & SC	$400,000.00	$400,000.00
233	7.1.2.2.5	Identify transportation & size reduction options	$200,000.00	$200,000.00
234	7.1.2.2.6	Provide information to assist partnership arrangements	$0.00	$0.00
235	**7.1.2.3**	**Perform economic and risk studies with scale-up data**	**$0.00**	**$403,603.20**
236	7.1.2.3.1	Evaluate yield and production cost variation data	$0.00	$110,073.60
237	7.1.2.3.2	Evaluate storage, handling, transportation cost variations	$0.00	$110,073.60
238	7.1.2.3.3	Evaluate financing and procurement strategies	$0.00	$183,456.00
239	7.1.2.3.4	Provide information to update business plans	$0.00	$0.00



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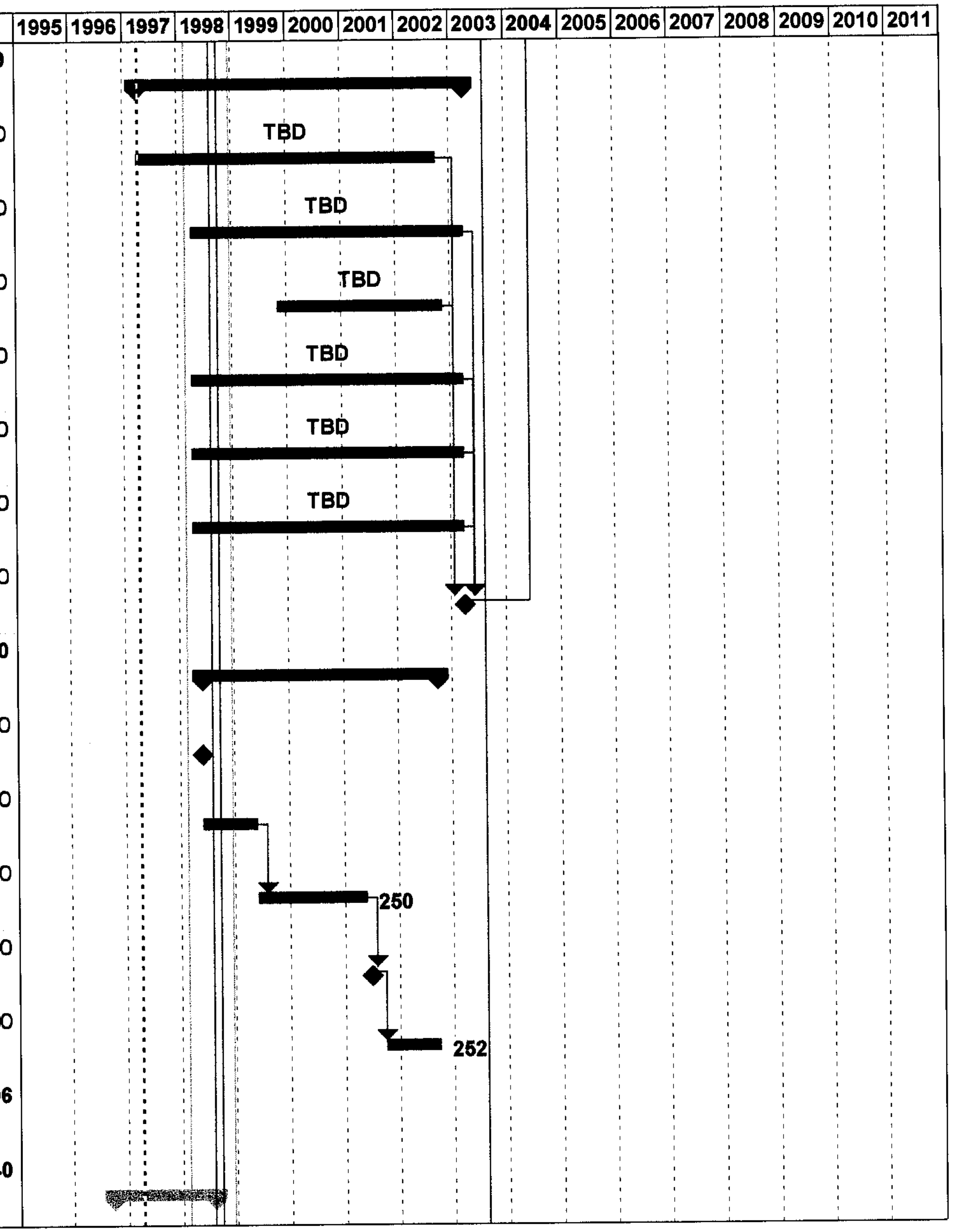
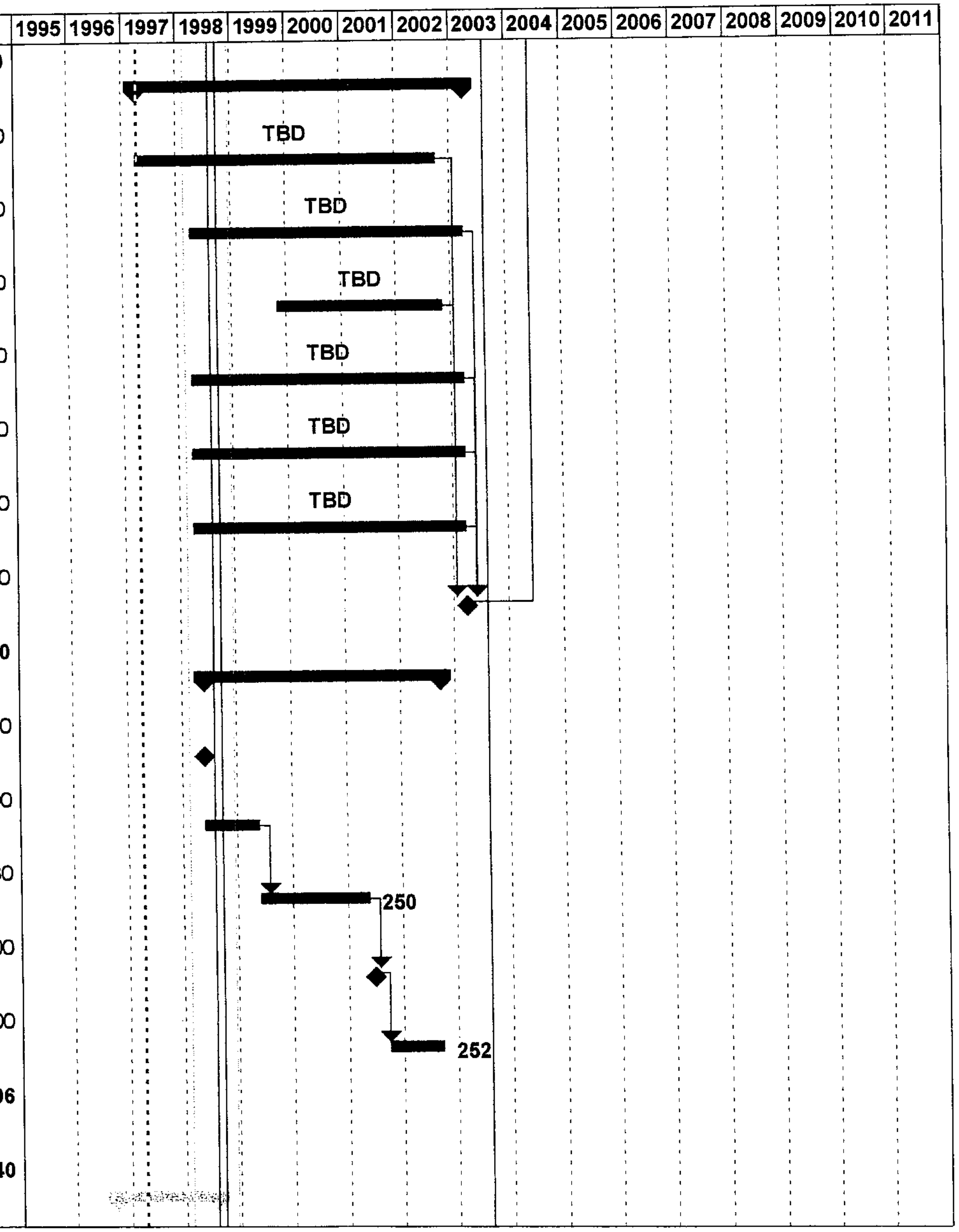
ID	WBS	Task Name	Fixed Cost	Total Cost
240	**7.1.2.4**	**Monitor and document environmental effects**	**$0.00**	**$730,000.00**
241	7.1.2.4.1	Monitor soil quality changes across Iowa Scaleup	$90,000.00	$90,000.00
242	7.1.2.4.2	Document biodiversity and wildlife habitat effects in Iowa Scaleup	$75,000.00	$75,000.00
243	7.1.2.4.3	Continue evaluating erosion & water quality effects in Iowa	$75,000.00	$75,000.00
244	7.1.2.4.4	Monitor soil quality changes across second scale-up	$90,000.00	$90,000.00
245	7.1.2.4.5	Monitor regional level water quality effects of second scale-up	$200,000.00	$200,000.00
246	7.1.2.4.6	Document biodiversity and wildlife habitat effects in second scale-up	$200,000.00	$200,000.00
247	7.1.2.4.7	Provide guidelines to demonstration project growers	$0.00	$0.00
248	**7.1.2.5**	**Establish switchgrass quality variation for ethanol conversion**	**$0.00**	**$1,044,140.80**
249	7.1.2.5.1	Identify feedstock characteristics relevant to SSF enzymatic hydrolysis conversion technology	$0.00	$0.00
250	7.1.2.5.2	Collect Samples from field trials representing range of conditions	$20,000.00	$111,728.00
251	7.1.2.5.3	Analyze feedstock samples for effects on ethanol processes	$200,000.00	$932,412.80
252	7.1.2.5.4	Handoff information & samples to ethanol process R&D	$0.00	$0.00
253	7.1.2.5.5	Integrate switchgrass to ethanol process at smallest possible scale	$0.00	$0.00
254	**7.2**	**Biomass Conversion Technology**	**$0.00**	**$43,287,288.96**
255	**7.2.1**	**Softwood-specific process integration and process development activities**	**$0.00**	**$947,040.40**



ID	WBS	Task Name	Fixed Cost	Total Cost
240	**7.1.2.4**	**Monitor and document environmental effects**	**$0.00**	**$730,000.00**
241	7.1.2.4.1	Monitor soil quality changes across Iowa Scaleup	$90,000.00	$90,000.00
242	7.1.2.4.2	Document biodiversity and wildlife habitat effects in Iowa Scaleup	$75,000.00	$75,000.00
243	7.1.2.4.3	Continue evaluating erosion & water quality effects in Iowa	$75,000.00	$75,000.00
244	7.1.2.4.4	Monitor soil quality changes across second scale-up	$90,000.00	$90,000.00
245	7.1.2.4.5	Monitor regional level water quality effects of second scale-up	$200,000.00	$200,000.00
246	7.1.2.4.6	Document biodiversity and wildlife habitat effects in second scale-up	$200,000.00	$200,000.00
247	7.1.2.4.7	Provide guidelines to demonstration project growers	$0.00	$0.00
248	**7.1.2.5**	**Establish switchgrass quality variation for ethanol conversion**	**$0.00**	**$1,044,140.80**
249	7.1.2.5.1	Identify feedstock characteristics relevant to SSF enzymatic hydrolysis conversion technology	$0.00	$0.00
250	7.1.2.5.2	Collect Samples from field trials representing range of conditions	$20,000.00	$111,728.00
251	7.1.2.5.3	Analyze feedstock samples for effects on ethanol processes	$200,000.00	$932,412.80
252	7.1.2.5.4	Handoff information & samples to ethanol process R&D	$0.00	$0.00
253	7.1.2.5.5	Integrate switchgrass to ethanol process at smallest possible scale	$0.00	$0.00
254	**7.2**	**Biomass Conversion Technology**	**$0.00**	**$43,287,288.96**
255	**7.2.1**	**Softwood-specific process integration and process development activities**	**$0.00**	**$947,040.40**



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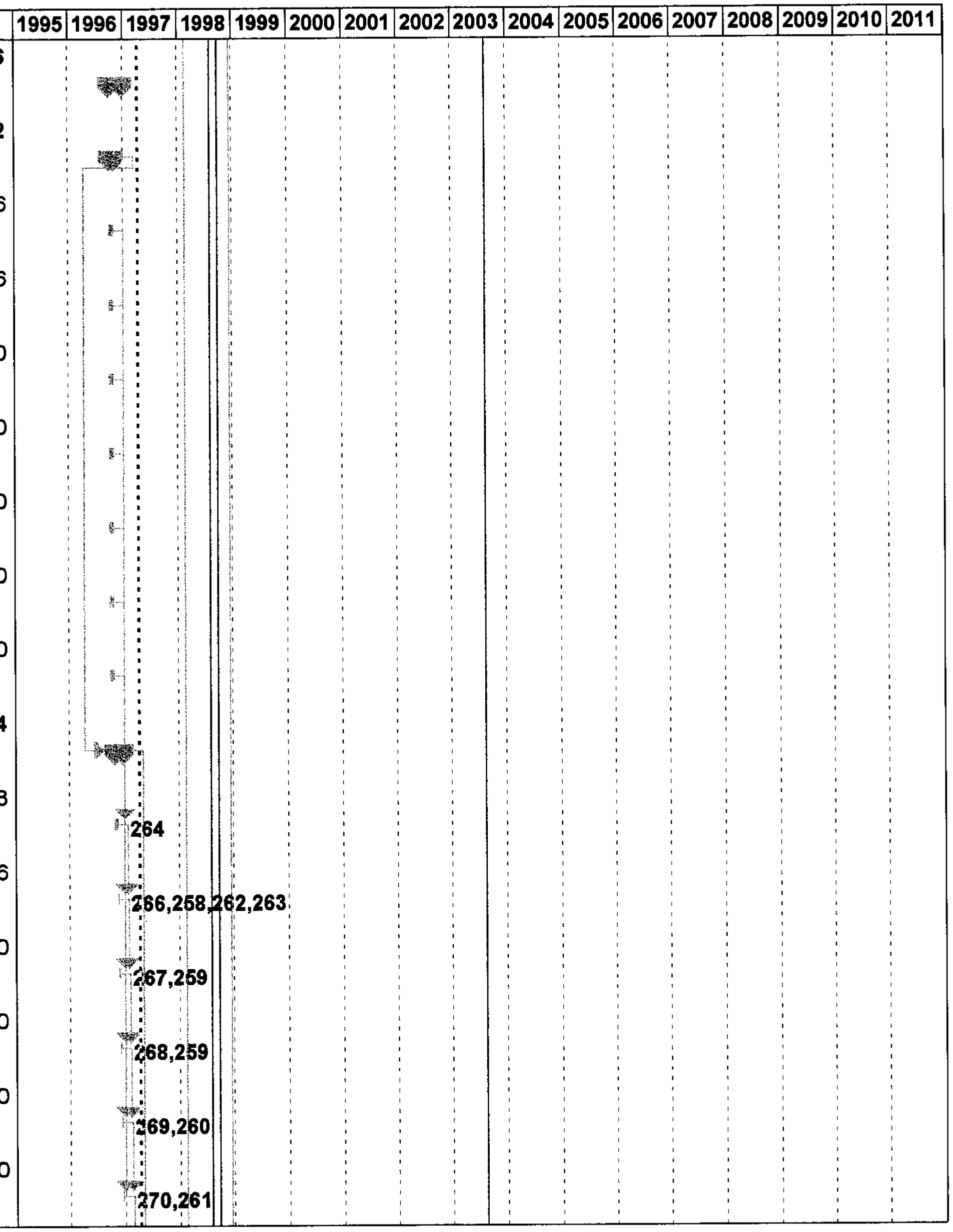
ID	WBS	Task Name	Fixed Cost	Total Cost
256	**7.2.1.1**	**Preliminary Technology Analysis**	**$0.00**	**$40,642.56**
257	**7.2.1.1.1**	**Investigate technologies**	**$0.00**	**$21,309.12**
258	7.2.1.1.1.1	SO2 steam explosion	$0.00	$1,834.56
259	7.2.1.1.1.2	Dilute acid hydrolysis	$0.00	$1,834.56
260	7.2.1.1.1.3	Concentrated acid	$0.00	$3,528.00
261	7.2.1.1.1.4	ACOS Organosolv process	$0.00	$3,528.00
262	7.2.1.1.1.5	Enzyme production	$0.00	$3,528.00
263	7.2.1.1.1.6	Fermentation/SHF/SSF	$0.00	$3,528.00
264	7.2.1.1.1.7	Lignin utilization	$0.00	$3,528.00
265	**7.2.1.1.2**	**Model 5 process options for softwoods**	**$0.00**	**$12,277.44**
266	7.2.1.1.2.1	Complete process & economic model	$0.00	$9,208.08
267	7.2.1.1.2.2	Option A	$0.00	$3,069.36
268	7.2.1.1.2.3	Option B	$0.00	$0.00
269	7.2.1.1.2.4	Option C	$0.00	$0.00
270	7.2.1.1.2.5	Option D	$0.00	$0.00
271	7.2.1.1.2.6	Option E	$0.00	$0.00



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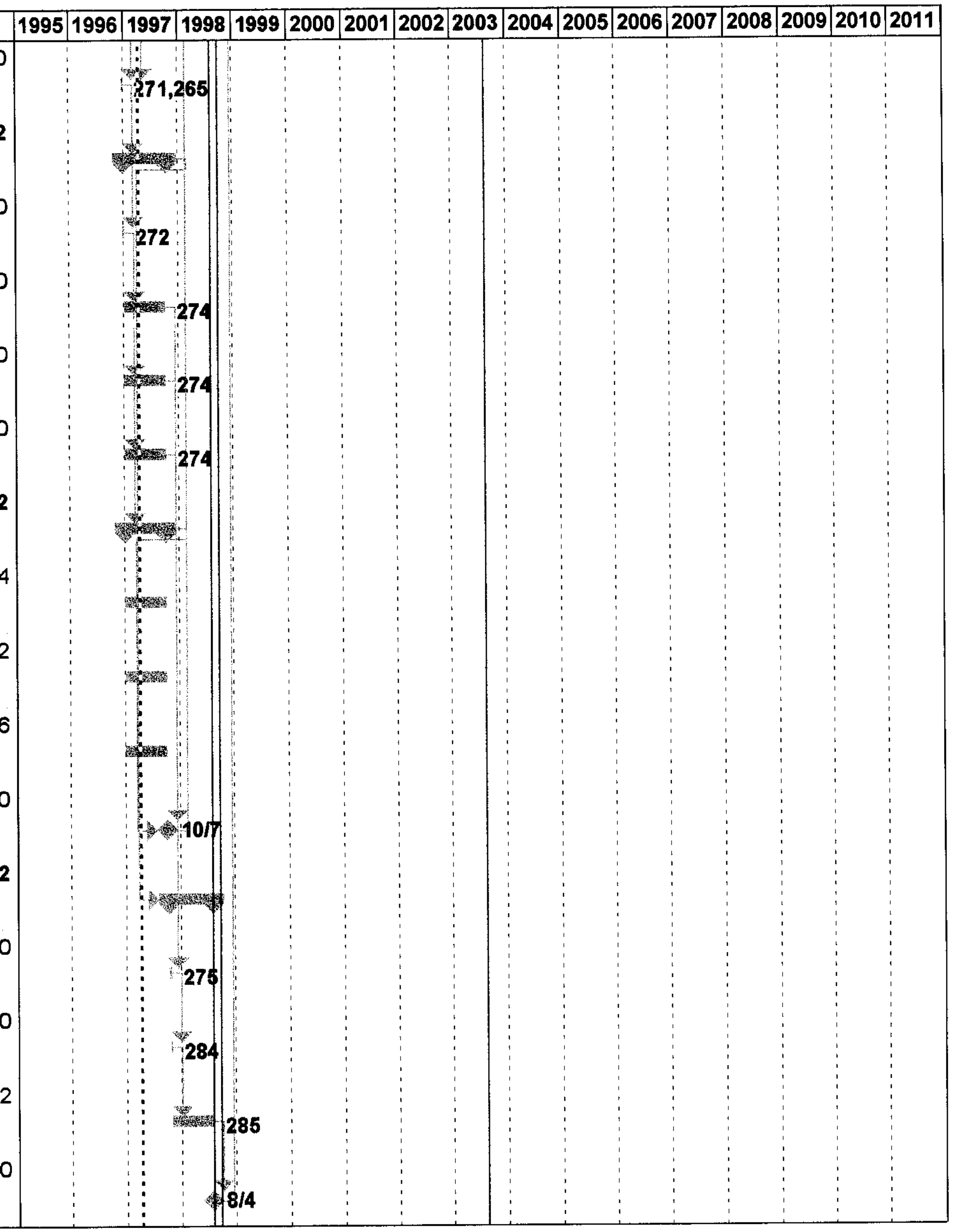
ID	WBS	Task Name	Fixed Cost	Total Cost
272	7.2.1.1.3	Identify technology gaps	$0.00	$7,056.00
273	**7.2.1.2**	**Fill Technology Gaps for Softwoods**	**$0.00**	**$673,525.12**
274	7.2.1.2.1	Revise softwoods technology plan	$0.00	$3,528.00
275	7.2.1.2.2	Subcontract or CRADA with UBC	$110,000.00	$123,759.20
276	7.2.1.2.3	Subcontract #2	$100,000.00	$113,759.20
277	7.2.1.2.4	Subcontract #3	$100,000.00	$113,759.20
278	**7.2.1.2.5**	**Pretreatment & fermentation work at NREL**	**$0.00**	**$283,439.52**
279	7.2.1.2.5.1	Dilute acid pretreatment	$0.00	$105,945.84
280	7.2.1.2.5.2	SO2 Steam explosion	$0.00	$35,773.92
281	7.2.1.2.5.3	C6 Fermentation R&D	$0.00	$141,719.76
282	7.2.1.2.6	Preliminary assessment of integrated technologies completed	$0.00	$35,280.00
283	**7.2.1.3**	**Process Selection and PDU Testing**	**$0.00**	**$232,872.72**
284	7.2.1.3.1	Revise Process Models	$50,000.00	$59,172.80
285	7.2.1.3.2	Select Process for further development	$0.00	$3,528.00
286	7.2.1.3.3	Subcontract #4	$100,000.00	$170,171.92
287	7.2.1.3.4	Integrated process for softwood to ethanol technology available for commercial development by industry	$0.00	$0.00



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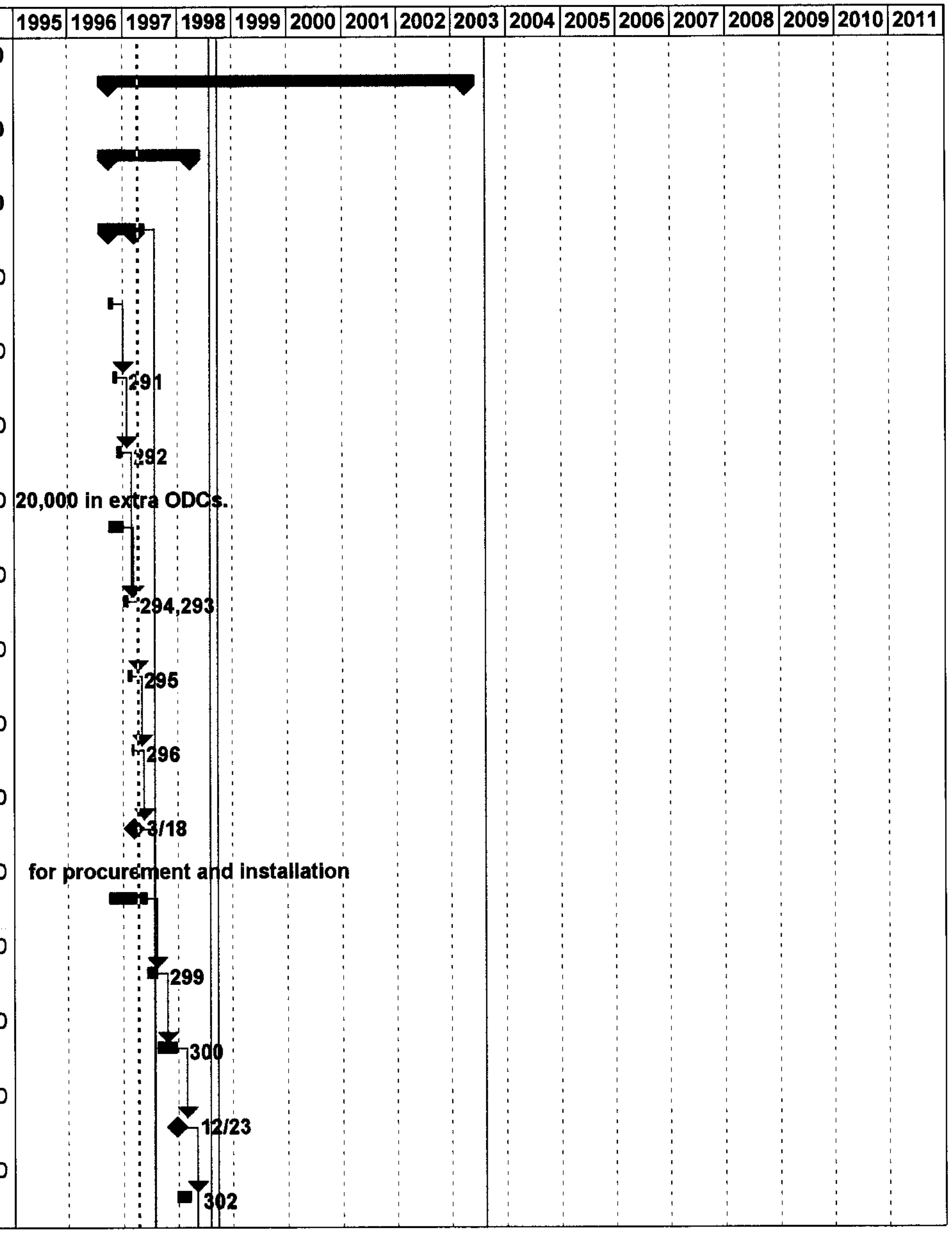
ID	WBS	Task Name	Fixed Cost	Total Cost
288	**7.2.2**	**Process Integration and Process Development**	**$0.00**	**$10,510,565.60**
289	**7.2.2.1**	**Provide commercial development facility capabilities to support industrial partners**	**$0.00**	**$1,342,109.60**
290	**7.2.2.1.1**	**Demonstrate an integrated process for ethanol from cellulose in a mini-pilot plant svstem**	**$0.00**	**$337,520.00**
291	7.2.2.1.1.1	Establish complete integrated process flow diagram for minipilot plant	$0.00	$7,056.00
292	7.2.2.1.1.2	Prove that aseptic conditions can be maintained in the biochemical conversion unit	$0.00	$28,224.00
293	7.2.2.1.1.3	Obtain approval to operate the mini-pilot plant using a genetically engineered microorganism	$0.00	$35,280.00
294	7.2.2.1.1.4	Design, procure and test ion exchange equipment for hydrolysate conditioning	$20,000.00	$168,176.00
295	7.2.2.1.1.5	Ready Sunds reactor to produce pretreated sawdust for integrated demonstration	$0.00	$28,224.00
296	7.2.2.1.1.6	Run process qualifier technology demonstration	$0.00	$56,448.00
297	7.2.2.1.1.7	Document process qualifier demonstration	$0.00	$14,112.00
298	7.2.2.1.1.8	Mini-pilot biochemical conversion unit available for commercial development	$0.00	$0.00
299	7.2.2.1.2	Design full pilot plant scale detoxification equipment	$400,000.00	$590,512.00
300	7.2.2.1.3	Install full pilot plant scale detoxification equipment	$0.00	$88,200.00
301	7.2.2.1.4	Test and modify full pilot scale detoxification equipment	$0.00	$190,512.00
302	7.2.2.1.5	Detoxification process available for pilot scale commercial development	$0.00	$0.00
303	7.2.2.1.6	Design SSCF system for pilot plant demonstration based on experimental results available	$0.00	$22,932.00



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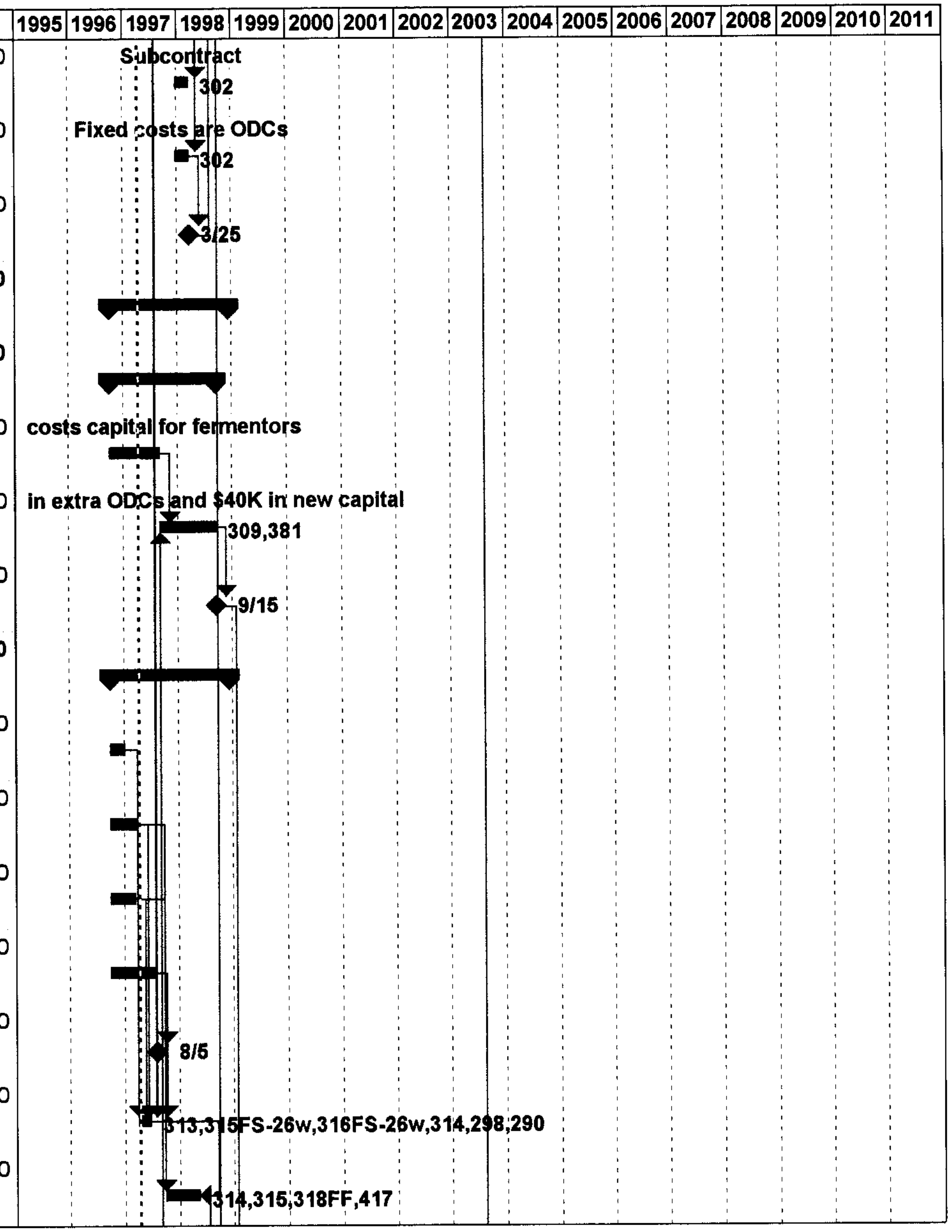
ID	WBS	Task Name	Fixed Cost	Total Cost
304	7.2.2.1.7	Evaluate spent solids for combustion value	$10,000.00	$32,932.00
305	7.2.2.1.8	Investigate the impacts of gypsum on the bioethanol process prior to pilot plant testing	$10,000.00	$78,796.00
306	7.2.2.1.9	Pilot scale testing capability available for use by commercial partners	$0.00	$705.60
307	**7.2.2.2**	**Provide integrated process technology for commercial development meeting the cost target of $1.13 /gal ethanol**	**$0.00**	**$4,215,144.00**
308	**7.2.2.2.1**	**Develop cellulase enzyme production technology utilizing hydrolysate and pretreated solids**	**$0.00**	**$1,784,352.00**
309	7.2.2.2.1.1	Establish cellulase production on hydrolysate and pretreated solids	$100,000.00	$862,048.00
310	7.2.2.2.1.2	Improve cellulase production on hydrolysate and pretreated solids based on induction protocol studies	$65,000.00	$922,304.00
311	7.2.2.2.1.3	Cellulase enzyme production technology available for commercial development	$0.00	$0.00
312	**7.2.2.2.2**	**Improve integrated process performance to achieve cost target for year 2000 deployment**	**$0.00**	**$2,430,792.00**
313	7.2.2.2.2.1	Produce pretreated and detoxified materials to meet team experimental needs	$0.00	$74,088.00
314	7.2.2.2.2.2	Improve pretreatment to increase cellulose digestibility and hemicellulose sugar yield	$0.00	$275,184.00
315	7.2.2.2.2.3	Develop Zymomonas strain adapted to 100 % hydrolysate	$0.00	$84,672.00
316	7.2.2.2.2.4	Complete detoxification process development at the bench scale	$0.00	$465,696.00
317	7.2.2.2.2.5	Provide data on applicability of detoxification to various feedstocks	$0.00	$0.00
318	7.2.2.2.2.6	Investigate SSCF performance by consideration of alternate process configurations	$0.00	$127,008.00
319	7.2.2.2.2.7	Investigate SSCF performance utilizing improved pretreatment, best detoxification and best performing Zymomonas	$0.00	$451,584.00



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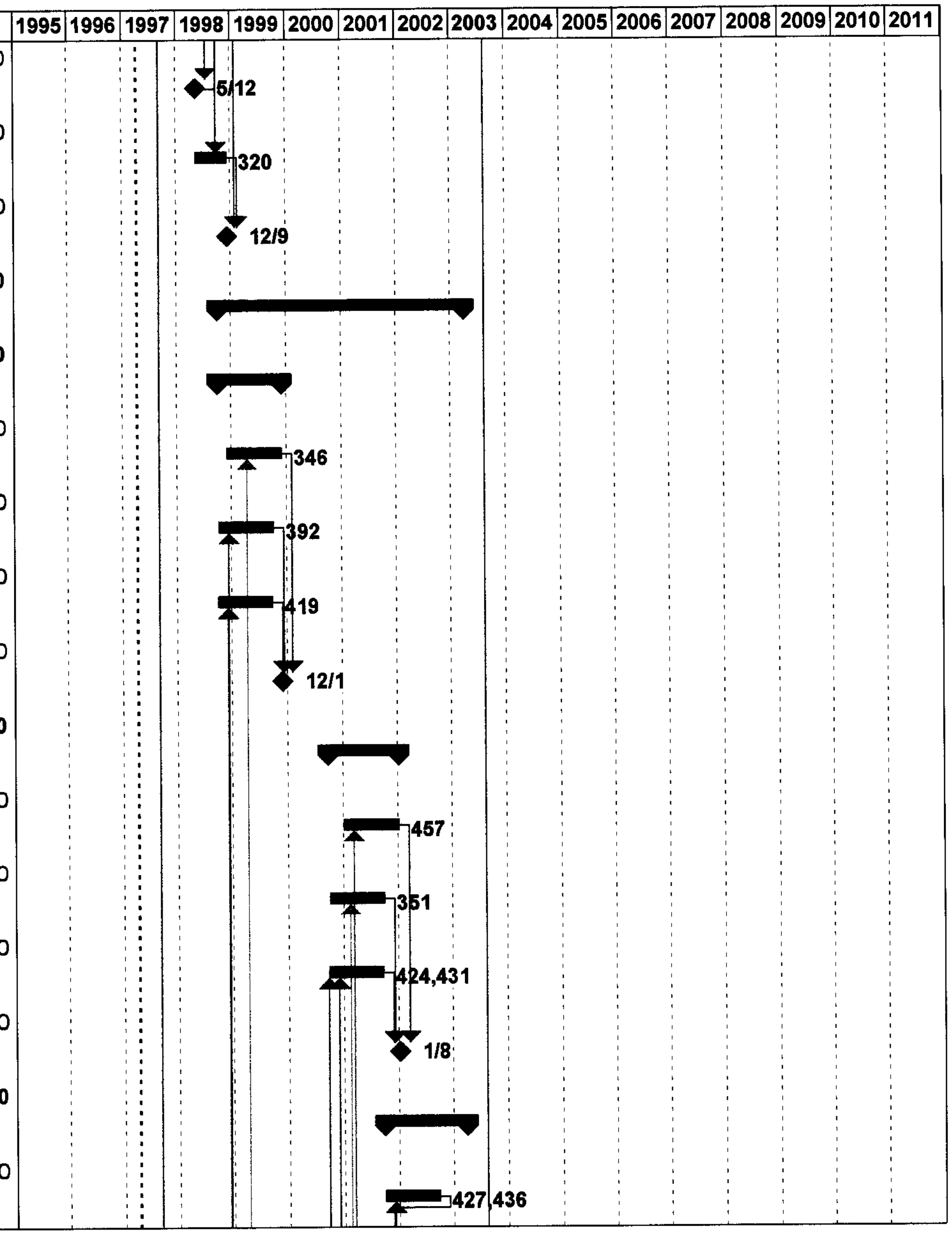
ID	WBS	Task Name	Fixed Cost	Total Cost
320	7.2.2.2.2.8	Improved process technology ready for review and generation of new improvement projects	$0.00	$0.00
321	7.2.2.2.2.9	Prioritized improvement projects carried out	$0.00	$952,560.00
322	7.2.2.2.2.10	Integrated biomass to ethanol technology meeting year 2000 performance available for commercial deployment	$0.00	$0.00
323	**7.2.2.3**	**Test incremental improvements under integrated process conditions**	**$0.00**	**$4,953,312.00**
324	**7.2.2.3.1**	**First roll-out of improvements in technology for near term waste feedstocks**	**$0.00**	**$1,651,104.00**
325	7.2.2.3.1.1	Test first generation countercurrent prehydrolysis technology in integrated process at the bench scale	$0.00	$550,368.00
326	7.2.2.3.1.2	Test Phase I genetically engineered cellulase system in integrated process at the bench scale	$0.00	$550,368.00
327	7.2.2.3.1.3	Test improved Zymomonas strain in integrated process at the bench scale	$0.00	$550,368.00
328	7.2.2.3.1.4	Documented improvements available for commercial deployment by industrial partners	$0.00	$0.00
329	**7.2.2.3.2**	**Second roll-out of improvements in technology for near term waste feedstocks**	**$0.00**	**$1,375,920.00**
330	7.2.2.3.2.1	Test lignin utilization technology	$0.00	$275,184.00
331	7.2.2.3.2.2	Test second generation countercurrent prehydrolysis technology at the bench scale	$0.00	$550,368.00
332	7.2.2.3.2.3	Test "super" Zymomonas strain (robust) and/or Lactobacillus at the bench scale	$0.00	$550,368.00
333	7.2.2.3.2.4	Improved low-value feedstock technology available for commercial development by industry	$0.00	$0.00
334	**7.2.2.3.3**	**Develop integrated process for switchgrass conversion that meets a target of $0.90/gal**	**$0.00**	**$1,926,288.00**
335	7.2.2.3.3.1	Test improvements in fermentor strains at the bench scale	$0.00	$550,368.00



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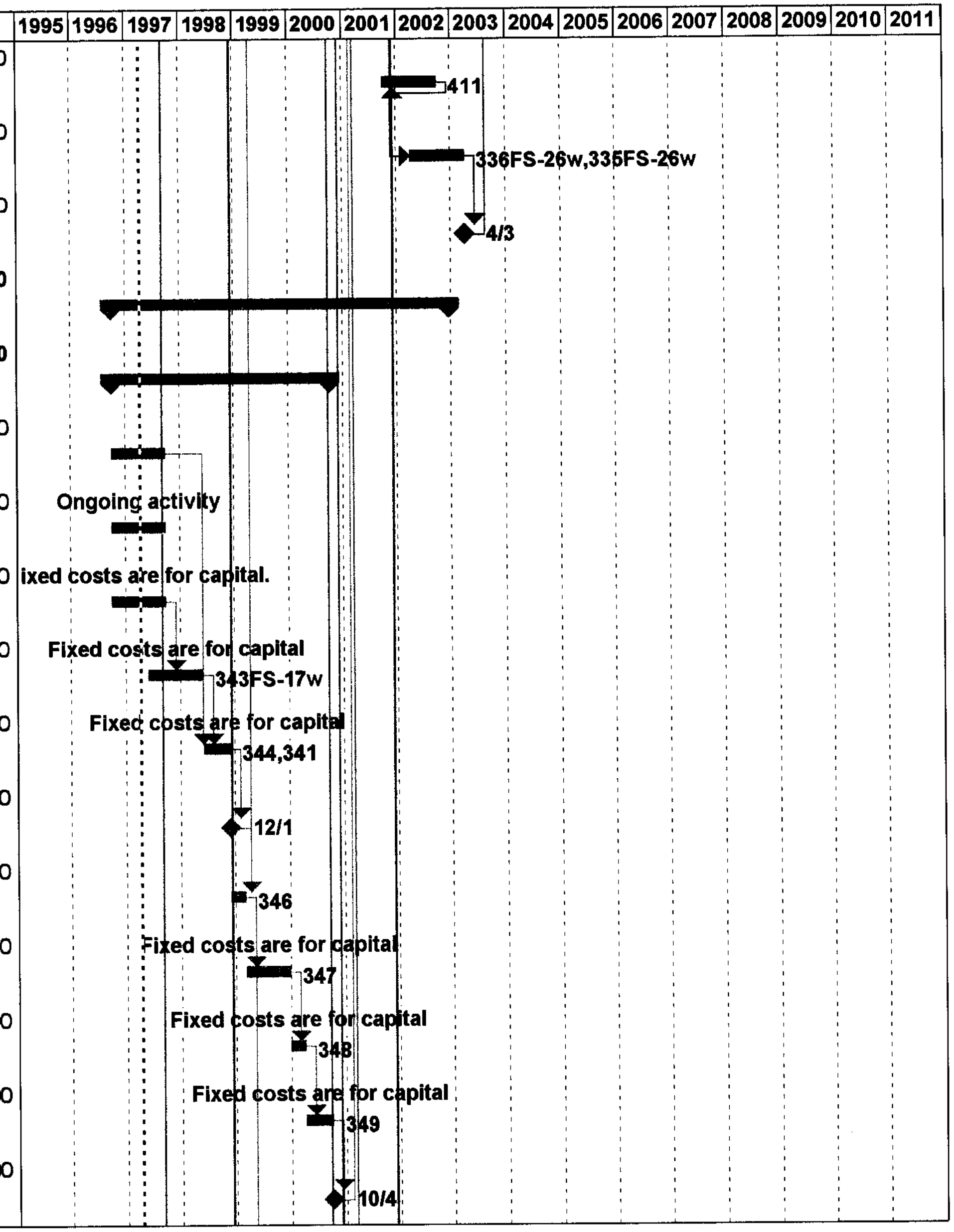
ID	WBS	Task Name	Fixed Cost	Total Cost
336	7.2.2.3.3.2	Test Phase II cellulase system at the bench scale	$0.00	$550,368.00
337	7.2.2.3.3.3	Integrate switchgrass to ethanol process at smallest possible scale	$0.00	$825,552.00
338	7.2.2.3.3.4	Switchgrass technology available for commercial development by industrial partners	$0.00	$0.00
339	**7.2.3**	**Chemical Hydrolysis R&D**	**$0.00**	**$8,826,754.40**
340	**7.2.3.1**	**Develop countercurrent chemical prehydrolysis technology**	**$0.00**	**$3,972,684.80**
341	7.2.3.1.1	Bench scale development of countercurrent chemical prehydrolysis	$100,000.00	$558,640.00
342	7.2.3.1.2	Supply test quantities of pretreated feedstocks for other unit operations	$50,000.00	$68,345.60
343	7.2.3.1.3	Design and procure a prototype reactor	$800,000.00	$1,166,912.00
344	7.2.3.1.4	Modify, expand PDU and install and shakedown all equipment	$300,000.00	$483,456.00
345	7.2.3.1.5	Test and modify prototype reactor	$200,000.00	$383,456.00
346	7.2.3.1.6	Hand-off prototype to EPD for integrated testing	$0.00	$0.00
347	7.2.3.1.7	Design second generation reactor	$0.00	$49,392.00
348	7.2.3.1.8	Procure second generation reactor	$800,000.00	$829,635.20
349	7.2.3.1.9	Install and shakedown second generation unit	$100,000.00	$149,392.00
350	7.2.3.1.10	Test and modify second generation unit	$100,000.00	$283,456.00
351	7.2.3.1.11	Hand-off second generation unit to EPD for integrated testing	$0.00	$0.00



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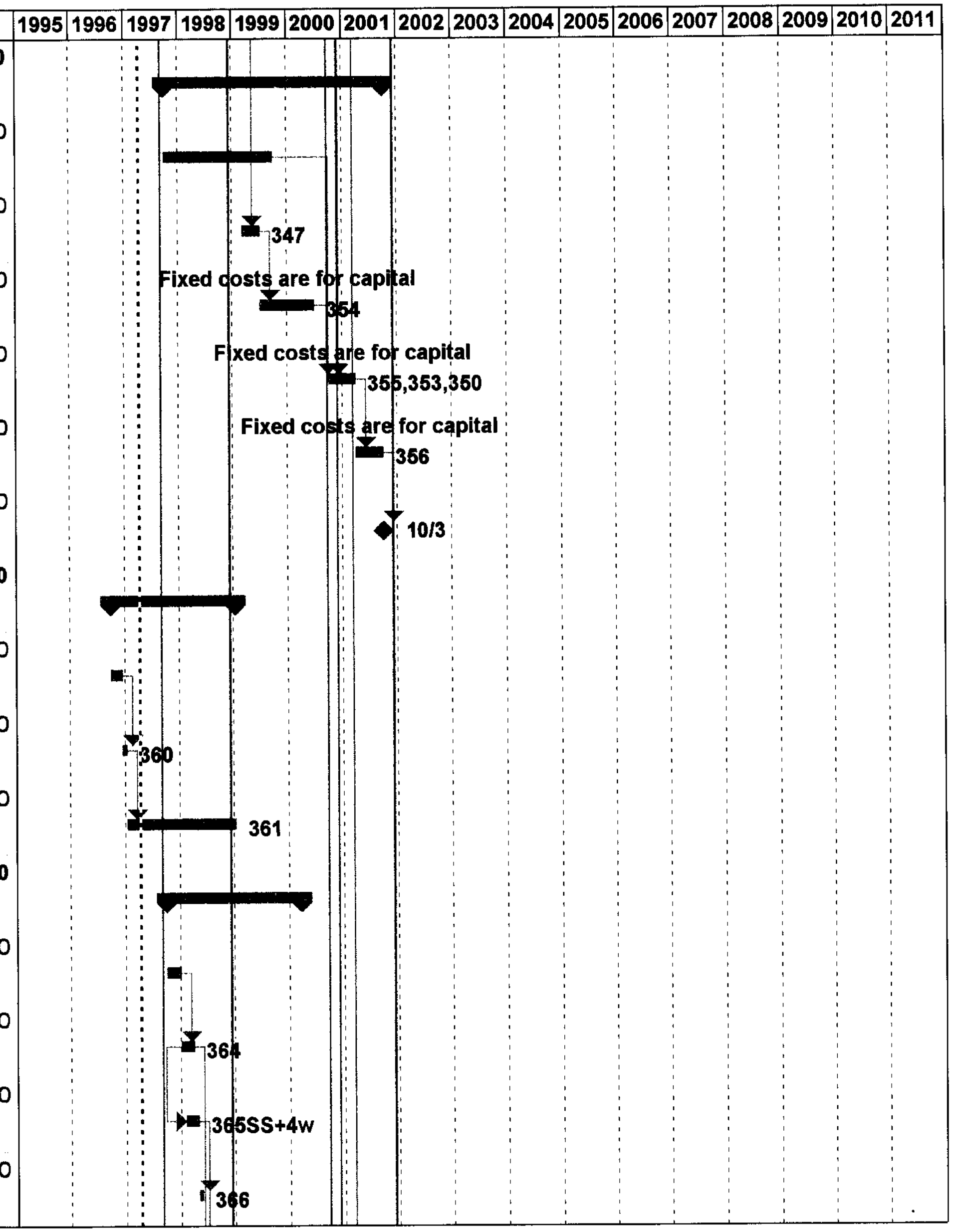
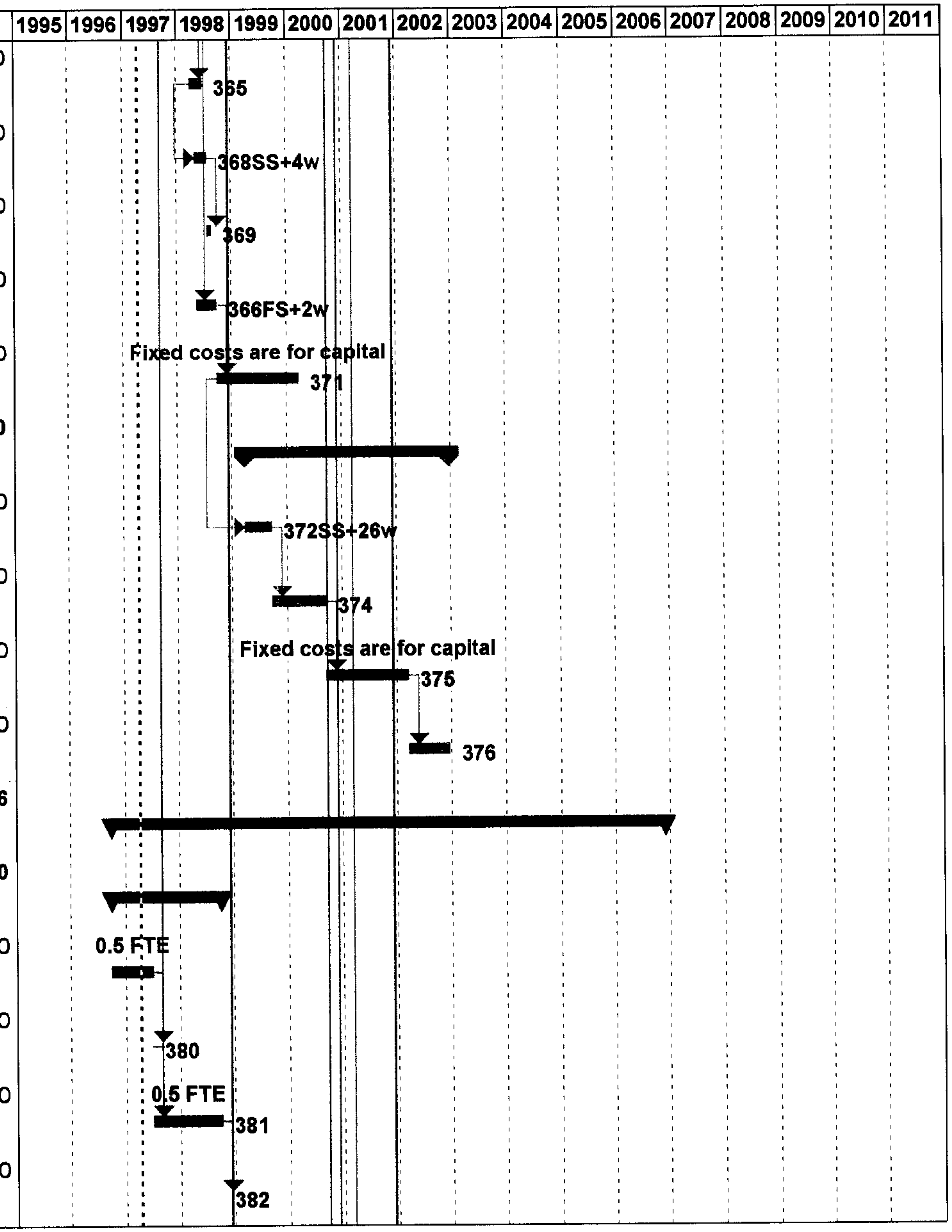
ID	WBS	Task Name	Fixed Cost	Total Cost
352	**7.2.3.2**	**Develop countercurrent complete chemical hydrolysis technology**	**$0.00**	**$2,289,131.20**
353	7.2.3.2.1	Bench scale development of countercurrent complete chemical hydrolysis	$300,000.00	$1,217,280.00
354	7.2.3.2.2	Design complete hydrolysis reactor	$0.00	$59,976.00
355	7.2.3.2.3	Procure complete hydrolysis reactor	$500,000.00	$536,691.20
356	7.2.3.2.4	Install and shakedown complete hydrolysis reactor	$100,000.00	$191,728.00
357	7.2.3.2.5	Initial testing of complete hydrolysis reactor	$100,000.00	$283,456.00
358	7.2.3.2.6	Hand-off second generation unit to EPD for integrated testing	$0.00	$0.00
359	**7.2.3.3**	**Alternate Pretreatment Evaluation**	**$0.00**	**$119,246.40**
360	7.2.3.3.1	Complete Data Analysis and Process Economic Evaluation of Alternate Pretreatments	$0.00	$38,808.00
361	7.2.3.3.2	Develop Strategy for Follow-on Alternate Pretreatment Work	$0.00	$7,056.00
362	7.2.3.3.3	Further Development/Scale up/Testing of Selected Promising Alternate Pretreatment(s)	$0.00	$73,382.40
363	**7.2.3.4**	**Long Term Feedstock (Hardwood) Bench Scale Development**	**$0.00**	**$1,228,412.00**
364	7.2.3.4.1	Identify and Obtain Representative Hardwood Samples	$0.00	$24,696.00
365	7.2.3.4.2	Determine Countercurrent Prehydrolysis Parameters for Hardwood	$0.00	$84,672.00
366	7.2.3.4.3	Determine Best Available Detox Methods for Hardwood Prehydrolysates	$0.00	$63,504.00
367	7.2.3.4.4	Quantify Material Balance, Solids Digestibility and Fermentability of Std. Detox. Prehydrolyzate	$0.00	$28,224.00



ID	WBS	Task Name	Fixed Cost	Total Cost
368	7.2.3.4.5	Determine Countercurrent Complete Hydrolysis Parameters for Hardwood	$0.00	$84,672.00
369	7.2.3.4.6	Determine Best Available Detox Methods for Hardwood Complete Hydrolyzates	$0.00	$63,504.00
370	7.2.3.4.7	Quantify Material Balance and Fermentability of Std. Detox. Hydrolyzate	$0.00	$28,224.00
371	7.2.3.4.8	Conduct Preliminary Process Engineering Analysis of Hardwood Countercurrent Pretreatment	$0.00	$100,548.00
372	7.2.3.4.9	Scale up Modification/Testing in Appropriate Countercurrent PDU Reactor	$200,000.00	$750,368.00
373	**7.2.3.5**	**Long Range Advanced Pretreatment Technologies**	**$0.00**	**$1,217,280.00**
374	7.2.3.5.1	Identify Advanced Pretreatment Technologies	$0.00	$45,864.00
375	7.2.3.5.2	Conduct Bench Scale Development Program on Selected Advanced Pretreatment Technologies	$200,000.00	$658,640.00
376	7.2.3.5.3	Identify and Obtain Appropriate Engineering Scale Reactor for Advanced Pretreatment Technology	$100,000.00	$237,592.00
377	7.2.3.5.4	Testing of Advanced Pretreatment Technologies at PDU Scale	$0.00	$275,184.00
378	**7.2.4**	**Enzyme Technology R&D**	**$0.00**	**$10,813,445.36**
379	**7.2.4.1**	**Near Term Enzyme R&D**	**$0.00**	**$159,112.80**
380	7.2.4.1.1	T. reesei: Decrease cellulase cost by optimizing induction protocols	$0.00	$68,796.00
381	7.2.4.1.2	Deliver new protocols to EPD	$0.00	$0.00
382	7.2.4.1.3	T. reesei: Determine effects of induction protocols on component enzymes	$0.00	$90,316.80
383	7.2.4.1.4	Report correlation between T. reesei induction and enzyme mix	$0.00	$0.00



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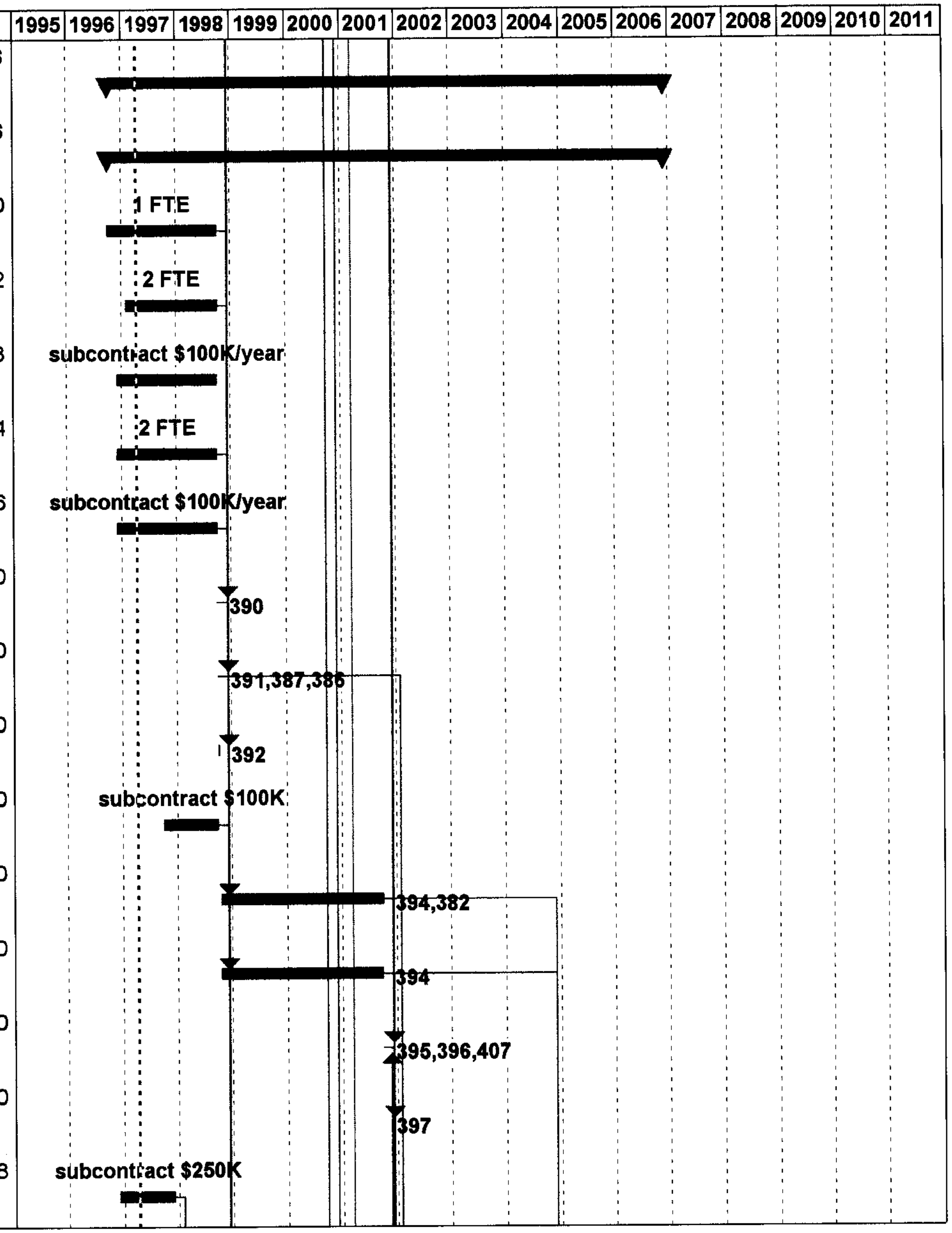
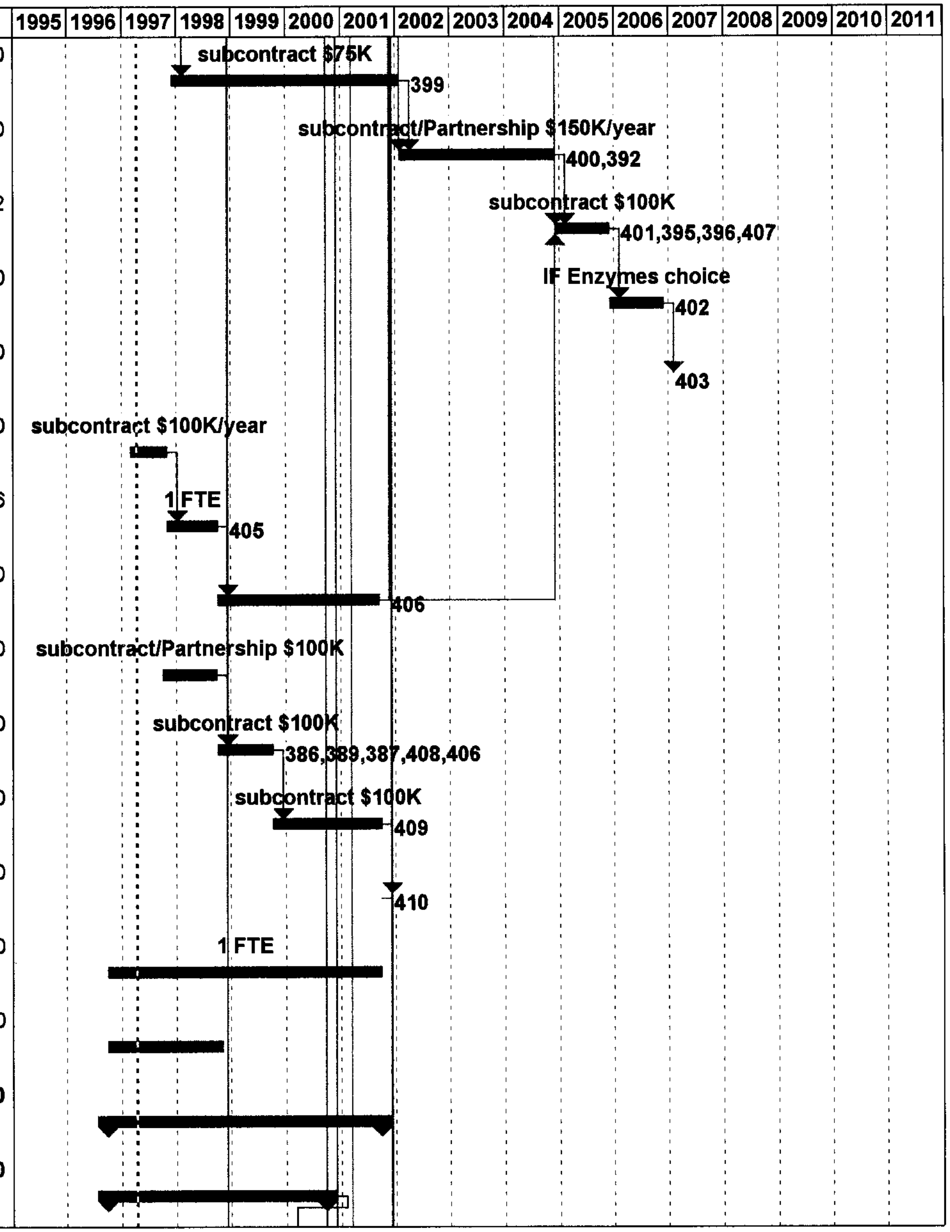
ID	WBS	Task Name	Fixed Cost	Total Cost
384	7.2.4.2	**Mid Term Enzyme R&D**	**$0.00**	**$10,654,332.56**
385	7.2.4.2.1	**Develop cost effective enzyme system for pretreated SG**	**$0.00**	**$10,654,332.56**
386	7.2.4.2.1.1	Phase I: Improve action of EI on pSG using site-directed mutagenesis	$0.00	$797,328.00
387	7.2.4.2.1.2	Phase I: Increase Topt and process tolerance of CBH I using SDM	$0.00	$522,990.72
388	7.2.4.2.1.3	Perform substrate/cellulose binding domain modeling for CBHI	$150,000.00	$183,727.68
389	7.2.4.2.1.4	Phase I: Increase Topt and process tolerance of E3 using SDM	$200,000.00	$216,863.84
390	7.2.4.2.1.5	Provide high resolution x-ray structure for E3 and clones of EI	$200,000.00	$210,125.36
391	7.2.4.2.1.6	Report K Milestone describing cellulase improvement by SDM	$0.00	$0.00
392	7.2.4.2.1.7	Deliver Phase I engineered cellulase system to EPD for testing	$0.00	$0.00
393	7.2.4.2.1.8	DECISION: Pick plant or submerged culture expression-continue w choice	$0.00	$0.00
394	7.2.4.2.1.9	Develop strategy to improve active site performance of cellulases	$5,000.00	$97,080.80
395	7.2.4.2.1.10	Phase II: Increase specific activity of CBHI on pSG using SDM	$0.00	$1,086,624.00
396	7.2.4.2.1.11	Phase II: Increase specific activity of E3 on pSG using SDM	$0.00	$1,085,212.80
397	7.2.4.2.1.12	Deliver Phase II engineered cellulase system w accessory enz to EPD for testing	$0.00	$0.00
398	7.2.4.2.1.13	DECISION: Pick enzymes or DMC	$0.00	$0.00
399	7.2.4.2.1.14	Produce rEI, rCBHI, and rE3 in 1st Gen plants	$200,000.00	$218,557.28



ID	WBS	Task Name	Fixed Cost	Total Cost
400	7.2.4.2.1.15	Evaluate field tests and enzyme recovery schemes	$5,000.00	$387,788.00
401	7.2.4.2.1.16	Produce rEI, rCBHI, and rE3 in 2nd Gen plant systems	$300,000.00	$352,214.40
402	7.2.4.2.1.17	Produce improved rEI, rCBHI, and rE3 in best field crops	$250,000.00	$268,486.72
403	7.2.4.2.1.18	Evaluate field tests and enzyme recovery schemes	$5,000.00	$96,375.20
404	7.2.4.2.1.19	Deliver technology for plant produced cellulases to EPD for modeling and testing	$0.00	$0.00
405	7.2.4.2.1.20	Provide purified accessory enz for testing at NREL	$0.00	$185,220.00
406	7.2.4.2.1.21	Determine utility of accessory enz (xylanases, cellodextrinases, etc) for hydrolysis of pSG	$180,000.00	$197,004.96
407	7.2.4.2.1.22	Improve Topt and process tolerance of accessory enzymes by SDM	$0.00	$1,086,624.00
408	7.2.4.2.1.23	Produce rEI, rCBHI, and E3 in submerged culture (Aspergillus, Trichoderma, Pichia)	$300,000.00	$392,080.80
409	7.2.4.2.1.24	Produce Phase I rEI, rCBHI, rE3, and/or accessory enzymes in submerged culture	$150,000.00	$242,433.60
410	7.2.4.2.1.25	Evaluate Gen II submerged culture production technologies with industry	$250,000.00	$433,103.20
411	7.2.4.2.1.26	Deliver mature technology for submerged culture production to EPD for modeling and testing	$0.00	$0.00
412	7.2.4.2.1.27	Evaluate new engineered cellulase/accessory enz systems as prepared	$0.00	$1,297,245.60
413	7.2.4.2.1.28	Evaluate enzymes expressed from best plant and/or submerged culture systems	$0.00	$1,297,245.60
414	**7.2.5**	**Fermentation Organism Development**	**$0.00**	**$9,321,512.00**
415	**7.2.5.1**	**Develop Zymomonas Organism for use in year 2000 waste to ethanol facility**	**$0.00**	**$4,944,304.00**



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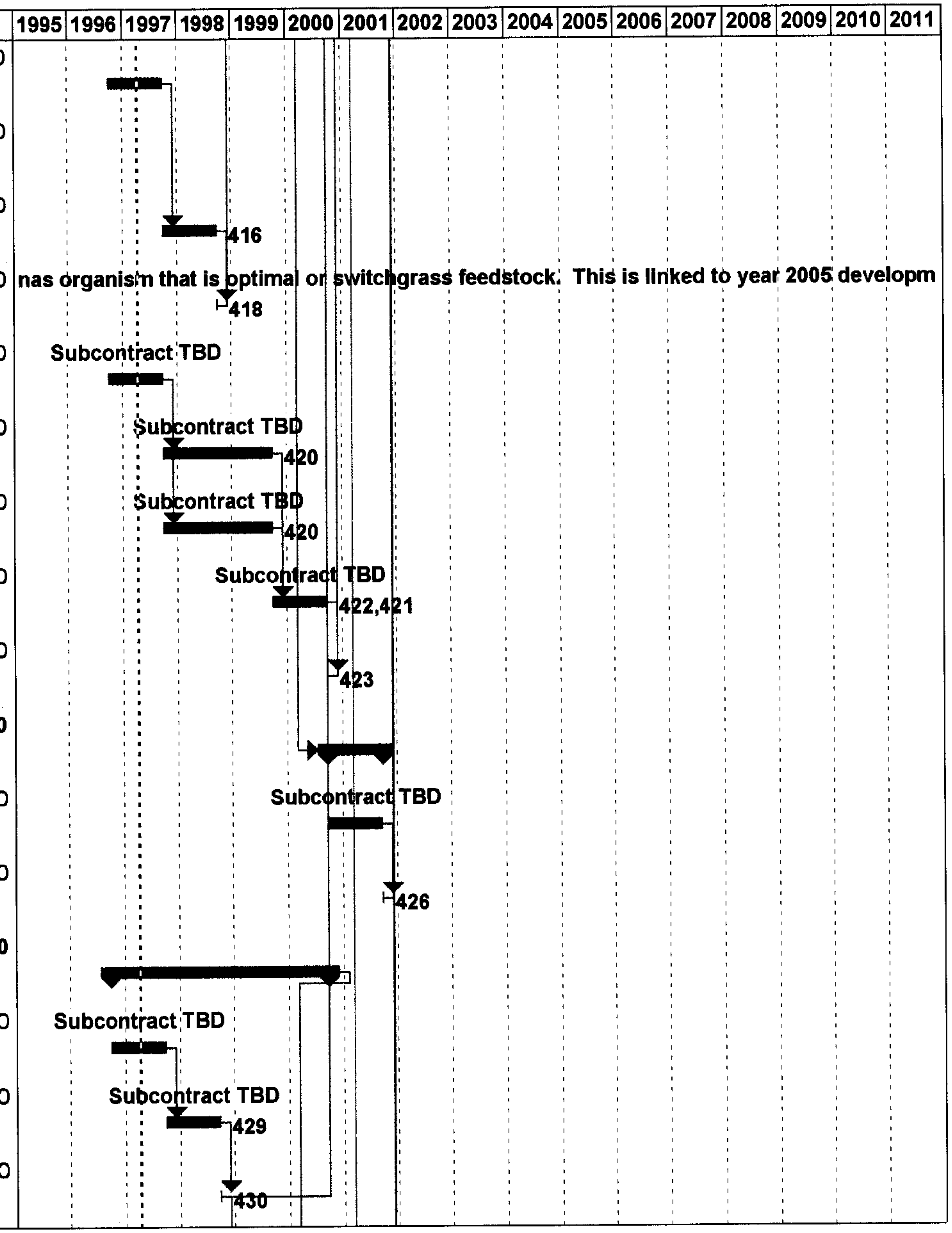
ID	WBS	Task Name	Fixed Cost	Total Cost
416	7.2.5.1.1	Evaluate new new Zymomonas strains	$0.00	$458,640.00
417	7.2.5.1.2	Select strains for hand-off to integration studies	$0.00	$0.00
418	7.2.5.1.3	Develop further improvements to Zymomonas organism	$0.00	$366,912.00
419	7.2.5.1.4	Hand-off improved Zymomonas strain for pilot scale demonstration work with industrial partner	$0.00	$0.00
420	7.2.5.1.5	Investigate new approaches to improving Zymomonas strain	$200,000.00	$933,824.00
421	7.2.5.1.6	Begin making metabolic enhancements of Zymomonas	$300,000.00	$1,033,824.00
422	7.2.5.1.7	Implement strategies to improve robustness of Zymomonas strain	$300,000.00	$1,217,280.00
423	7.2.5.1.8	Develop a "super" Zymomonas strain with desired robustness and sugar utilization characteristics	$200,000.00	$933,824.00
424	7.2.5.1.9	Hand-off advanced Zymomonas strains to industrial partner for use in commercial facility	$0.00	$0.00
425	**7.2.5.2**	**Develop Zymomonas Organism for use in year 2005 switchgrass to ethanol facility**	**$0.00**	**$933,824.00**
426	7.2.5.2.1	Make adjustments switchgrass	$200,000.00	$933,824.00
427	7.2.5.2.2	Hand-off switchgrass Zymomonas strain to EPD for integration studies	$0.00	$0.00
428	**7.2.5.3**	**Develop a Lactobacillus strain for improved performance and robustness**	**$0.00**	**$2,693,016.00**
429	7.2.5.3.1	Re-initiate work on lactobacillus	$75,000.00	$258,456.00
430	7.2.5.3.2	Develop an ethanol producing lactobacillus	$200,000.00	$566,912.00
431	7.2.5.3.3	Hand-off lactobacillus to EPD for integration and PDU studies	$0.00	$0.00



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ID	WBS	Task Name	Fixed Cost	Total Cost	1995–2011
432	7.2.5.3.4	Assess and improve lactobacillus strains	$400,000.00	$1,867,648.00	Subcontract TBD; 431
433	7.2.5.3.5	Hand-off lactobacillus organism to EPD for integration and pilot scale studies	$0.00	$0.00	432
434	**7.2.5.4**	**Develop Lactobacillus strain for use in year 2005 switchgrass to ethanol facility**	**$0.00**	**$750,368.00**	
435	7.2.5.4.1	Make adjustments for switchgrass sugars as needed	$200,000.00	$750,368.00	Subcontract TBD
436	7.2.5.4.2	Hand-off switchgrass Lactobacillus strain to EPD for testing	$0.00	$0.00	435
437	**7.2.6**	**Direct Microbial Conversion Strain Development**	**$0.00**	**$1,564,315.20**	
438	**7.2.6.1**	**Develop cost effective Zymomonas strains for DMC process**	**$0.00**	**$1,564,315.20**	
439	7.2.6.1.1	Acquire or produce cDNA clone of best beta-glucosidase or cellobiase	$0.00	$184,514.40	FTE of enzyme researcher
440	7.2.6.1.2	Clone cellobiase in best "Z" using best expression vectors	$0.00	$92,080.80	439
441	7.2.6.1.3	Deliver cellobiose fermenting "Z" to EPT for testing	$0.00	$0.00	440
442	7.2.6.1.4	Develop integrated transformation system for Z, using cellobiase gene	$0.00	$551,073.60	subcontract $100K/year; 441
443	7.2.6.1.5	Clone rEI and rCBHI in best "Z" or Lactobacillus	$0.00	$736,646.40	IF DMC choice; 395,442
444	7.2.6.1.6	Deliver engineered "Z" or Lactobacillus to EPT for testing	$0.00	$0.00	443
445	**7.2.7**	**Lignin Utilization R & D**	**$0.00**	**$1,303,656.00**	
446	7.2.7.1	Technoeconomic analysis	$0.00	$48,686.40	
447	7.2.7.2	Lab optimization of BCD	$150,000.00	$1,254,969.60	o details. Labor, subs from '97 AOP

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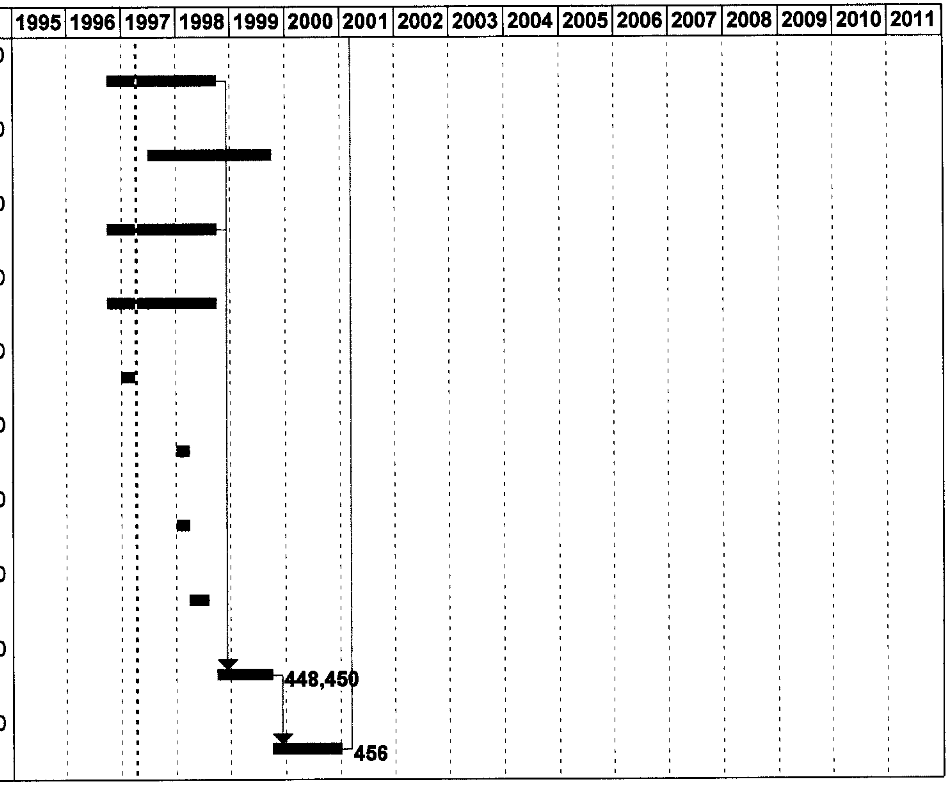
ID		WBS	Task Name	Fixed Cost	Total Cost
448		7.2.7.3	Reproducibility and batch scale-up	$0.00	$0.00
449		7.2.7.4	Supply lignin to Utah, Sandia and NREL	$0.00	$0.00
450		7.2.7.5	Jet reactor BCD process work	$0.00	$0.00
451		7.2.7.6	Analysis of BCD products	$0.00	$0.00
452		7.2.7.7	Detailed flow diagram: BCD/HPR	$0.00	$0.00
453		7.2.7.8	Detailed flow diagram:E+SHR	$0.00	$0.00
454		7.2.7.9	Evaluation/ determine product targets	$0.00	$0.00
455		7.2.7.10	Technoeconomic analysis of best products	$0.00	$0.00
456		7.2.7.11	Scale-up of jet or other reactor	$0.00	$0.00
457		7.2.7.12	Pilot plant testing of new reactor	$0.00	$0.00



7. Resource-Loading the Plan

An essential part of the plan for the Bioethanol Project is estimating the resource requirements and budgets for meeting the near term and mid term goals. We have developed ball park estimates for all of the activities in the plan based on discussions with the research team leaders responsible for each of the major areas of the plan. These areas have been defined as follows:

1. Feedstock Production
2. Chemical Hydrolysis
3. Enzyme Research
4. Fermentation Organism
5. Softwoods Research
6. Process Development
7. Pilot Plant Operations
8. Partnership Development
9. Lignin Research

Resources have been organized in the plan using these categories. This enables us to look in more detail at where the bottlenecks for our resources exist.

7.1 Establishing the Resource Pool

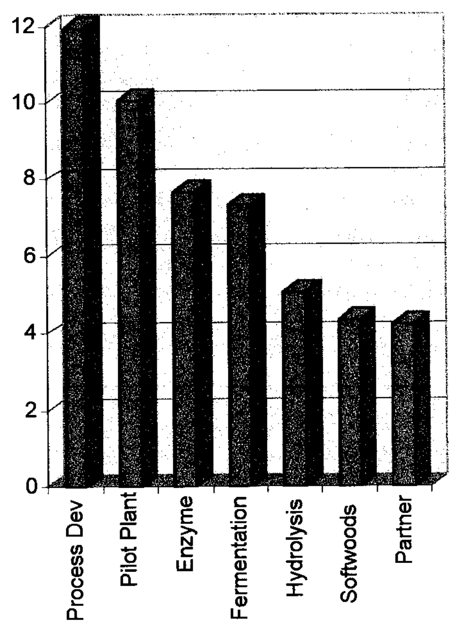
Table 5 is an object link embedded table taken directly from the Microsoft Project™ file for the bioethanol project prior to leveling of resources. It shows the same nine resources categories listed in the previous section along with an estimate of the total number of such resources available. Those resources highlighted in red are all identified as having peak resource demands higher than what is available in the resource pool. The plain text resources are allocated within available levels.

The units of resource availability are essentially "full time equivalents" (FTEs). In order to quantify the number of resources available in each category, we used a complete list of teams and team members for the project as defined within the Biotechnology Center at NREL (see Table 6). The split of available time for team members who are on more than one team is approximate. Also, it is really difficult to distinguish a resource defined as a process development researcher versus one defined as a pilot plant researcher.

Table 5: Microsoft Project Resource Sheet for MYTP

ID	Resource Name	Initials	Group	Units	Std. Rate	Accrue At	Calendar
1	**Enzyme Researcher**	**ENZ**	**NREL**	**7.68**	**$88.20/h**	**Prorated**	**Standard**
2	**Fermentation Researcher**	**FER**	**NREL**	**7.33**	**$88.20/h**	**Prorated**	**Standard**
3	**Chemical Hydrolysis Researcher**	**HYD**	**NREL**	**5.08**	**$88.20/h**	**Prorated**	**Standard**
4	**Softwoods Researcher**	**SFT**	**NREL**	**4.33**	**$88.20/h**	**Prorated**	**Standard**
5	Feedstock Researcher	FEED	ORNL	10	$88.20/h	Prorated	Standard
6	**Pilot Plant Researcher**	**PDU**	**NREL**	**10.75**	**$88.20/h**	**Prorated**	**Standard**
7	**Partnership Development**	**PDT**	**NREL**	**4.22**	**$88.20/h**	**Prorated**	**Standard**
8	**Process Development**	**PD**	**NREL**	**11.25**	**$88.20/h**	**Prorated**	**Standard**
9	Lignin Researcher	L	NREL	10	$88.20/h	Prorated	Standard
10							

Figure 11 Relative Distribution of Resources for Conversion Technology



To an extent, these resources may be interchangeable. So there is a certain arbitrariness to the distribution of current resources shown here. Our resource analysis is also limited by the fact that the resource distribution is assumed to be static. In other words, we ignored the possibility of shifting resource support among the different areas over time. Realistically, this type of shifting is what will happen.

Because of limits in time, we did not determine the size of the resource base for two of the categories: feedstock research and lignin research. The number of FTEs available for these areas was selected arbitrarily higher than the peak demand for that resource. Thus, when resource-leveling was done, it did not consider any possible limitations in these two areas.

Figure 11 shows a graphical break down of the resources available for the project. This graph shows that process development and pilot plant resources are far and away the greatest proportion of our current resource base. This makes sense given the high priority on meeting a year 2000 deployment target.

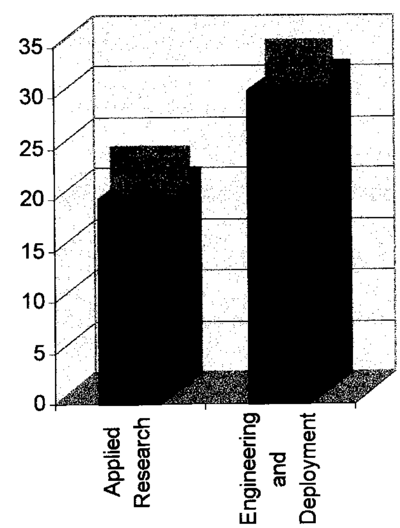


Figure 10 Applied Research versus Engineering and Deployment Resources

Table 6: NREL Team Resources for Conversion Technology

	ENZ	FER	HYD	PDU	EPD	SFT	PDT	FEED	PRG	Total
Adney, Bill	1	0	0	0	0		0	0	0	1
Aire, Mike	0	0	0	0	0.5	0.5	0	0	0	1
Andrews, Kris ++	0	0	0	0	0	0	0	0	1	1
Baker, John	1	0	0	0	0	0	0	0	0	1
Bates, Delicia	0	0	0	0	0	1	0	0	0	1
Boynton, Brian	0	0	0	0.5	0	0.5	0	0	0	1
Brown, Larry W.	0	0	0.5	0.5	0	0	0	0	0	1
Chou, Yat-Chen	0	1	0	0	0	0	0	0	0	1
Danielson, Nathan	0	1	0	0	0	0	0	0	0	1
Decker, Steve	1	0	0	0	0	0	0	0	0	1
Eddy, Fannie	0	0	0	0.5	0.25	0.25	0	0	0	1
Ehrman, Tina	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0	1
Elander, Rick	0	0	1	0	0	0	0	0	0	1
Evans, Kent	1	0	0	0	0	0	0	0	0	1
Farmer, Jody	0	0	0	0.5	0.5	0	0	0	0	1
Finkelstein, Mark	0	0.5				0.25			0.25	1
Glassner, David ++	0	0	0	0	0	0	0	0	1	1
Godbole, Shubhada	1	0	0	0	0	0	0	0	0	1
Hayward, Tammy Kay	0	0	0.5	0.5	0	0	0	0	0	1
Himmel, Mike	0.8	0	0	0	0	0	0.1	0	0.1	1
Hinman, Norm	0	0	0	0	0	0	0.9	0	0.1	1
Hora, James	0	0	0.5	0	0	0.5	0	0	0	1
Ibsen, Kelly	0	0	0	1	0	0	0	0	0	1
Ingle, Netta	0	0	0	0.5	0.5	0	0	0	0	1
Jennings, Ed	0	0	0	1	0	0	0	0	0	1
Johnston, Tim	0	0	0	1	0	0	0	0	0	1
Kadam, Kiran	0	0	0	0	0.1	0	0.8	0	0.1	1
Keller, Fred	0	0	0	0	1	0	0	0	0	1
Lai, Xiaokuang	0	1	0	0	0	0	0	0	0	1
Long, Janet	0	0	0	0	1	0	0	0	0	1
Lumberg, Lyn	0	0	0	0	0	0	0.8	0	0.2	1
Lyons, Bob	0	0	0	1	0	0	0	0	0	1
Mares, Ben	?	?	?	?	?	?	?	?	?	0
Mistrey, Steve	0	1	0	0	0	0	0	0	0	1
Mohagheghi, Ali	0	0.5		0	0.5	0	0	0	0	1
McMillan, Jim	0	0	0	0	1	0	0	0	0	1
Nagle, Nick	0	0	1	0	0	0	0	0	0	1
Newman, Mildred	0	0	0	0	1	0	0	0	0	1
Nguyen, Quang	0	0	0	0	0	1	0	0	0	1
Nieves, Rafael	1	0	0	0	0	0	0	0	0	1
Patton, Traci	0	0	0	0	0	0	0	0	1	1
Plummer, Tim	0	0	0	1	0	0	0	0	0	1
Rice, Dana	0	0	0.2	0	0.8	0	0	0	0	1
Riley, Cindy	0	0	0	0	0	0	0	0	1	1
Ruiz, Raymond	0	0	0.25	0.25	0.25	0.25	0	0	0	1
Ruth, Mark	0	0	0	0	1	0	0	0	0	1
Schell, Dan	0	0	0	0.8	0	0.2	0	0	0	1
Schmidt, Sherry	0	0	0	0	1	0	0	0	0	1
Sheehan, John	0	0	0	0	0	0	0	0	1	1
Short, David	0	0	0	0	1	0	0	0	0	1
Templeton, David	0	0.2	0	0.4	0.4	0	0	0	0	1
Thomas, Steve	1	0	0	0	0	0	0	0	0	1
Torget, Bob	0	0	1	0	0	0	0	0	0	1
Tucker, Mel	0	0	0	0.5	0.25	0.25	0	0	0	1
Tyson, Shaine	0	0	0	0	0	0	0	0	1	1
Vinzant, Todd	0.25	0.5	0	0	0.25	0	0	0	0	1
Willson, Liz	0.5	0.5	0	0	0	0	0	0	0	1
Wiselogel, Art	0	0	0	0	0	0	0.5	0	0.5	1
Wooley, Bob	0	0	0	0	1	0	0	0	0	1
Yancey, Mark	0	0	0	0	0	0	1	0	0	1
Zhang, Min	0	1	0	0	0	0	0	0	0	1
Total	7.675	7.325	5.075	10.075	11.925	4.325	4.225	0.125	6.25	57

When these resources are consolidated into applied research and engineering/ deployment activities, we see that 60% of the resources planned for the near and mid term goals are dedicated to deployment and process scale-up activities (see Figure 10). The bulk of activities in the applied research areas are in support of mid term deployment-related goals.

7.2 Resource Allocation Methodology

In the previous section, we presented an analysis of *existing* resources as allocated in FY 1997. The following sections describe resource allocation requirements based on the multi-year technical plan itself.

For each major area, researchers were asked to assess both in-house and subcontract requirements to meet the deadlines and durations shown in the plan. As an example, if a given activity lasts for 6 months, then team leaders provided input as to how many FTEs would have to be assigned to get the job done during that six month period. Likewise, if the work called for the use of subcontractors to get the work done, the cost of the subcontract was estimated, In some cases, special requirements for capital costs were provided if known.

Team leaders were explicitly told NOT to consider current budget or resource constraints. They provided estimates strictly on what was required for the tasks described in the plan.

Input from team leaders was entered in an Excel™ spreadsheet which calculated the actual amount of work required for the task. This is a subtlety of great importance. Work in this case is defined as the duration of the task times the number of FTEs assigned to it. Entered in this way, the resource data is much more robust. It allows us to change resource assignments and see the impacts on scheduling. In addition, it allows us to resource-level the plan using automated subroutines available in Microsoft

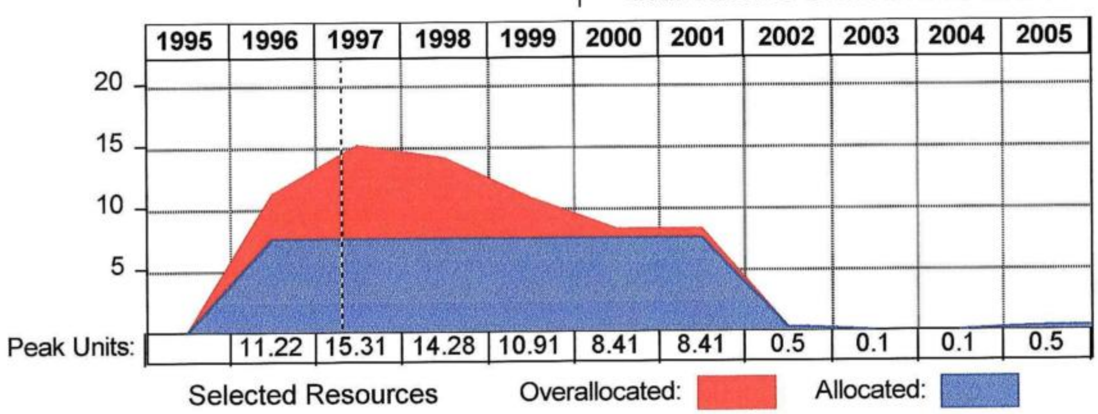


Figure 12 Resource Allocation for Enzyme Research

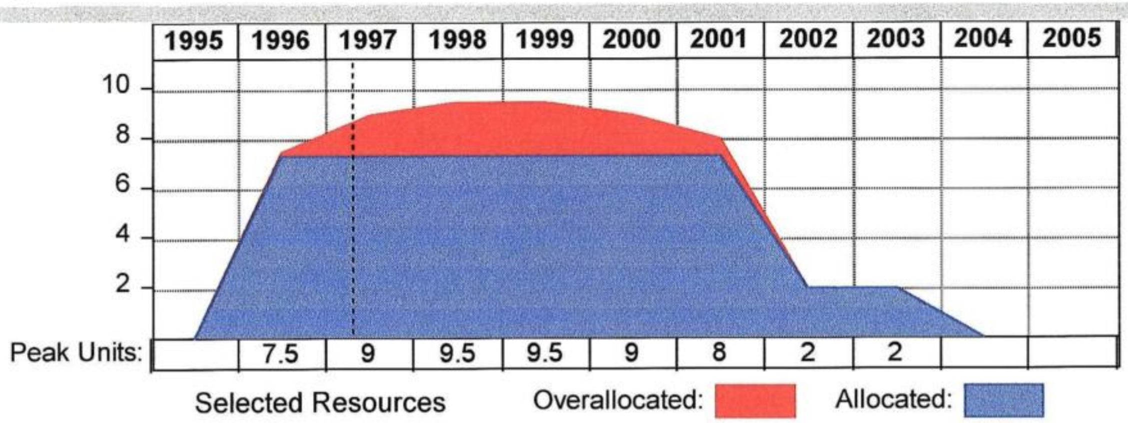


Figure 13 Resource Allocation for Fermentation Research

Project™. All of resource worksheets are shown at the end of Section 6.

7.3 Enzyme Research Resource Analysis

Figure 12 shows a resource graph generated by Microsoft Project™ for enzyme researchers. The graph points out that enzyme research resources are overallocated by a factor of two in FY 1997 and 1998 under the current plan. This should not come as a surprise since no real thought was given to resource assignments when the plan was first developed. Later in this section we will show what has to happen to the schedule in order to get current resource assignments aligned with resource requirements for the plan.

7.4 Fermentation Organism Research Resource Analysis

Figure 13 shows the resource allocation graph for fermentation organism development. Alignment between resource assignments and requirements is pretty good in this case, though a roughly 20% allocation of resources is occurring in the first three years of the plan.

7.5 Chemical Hydrolysis

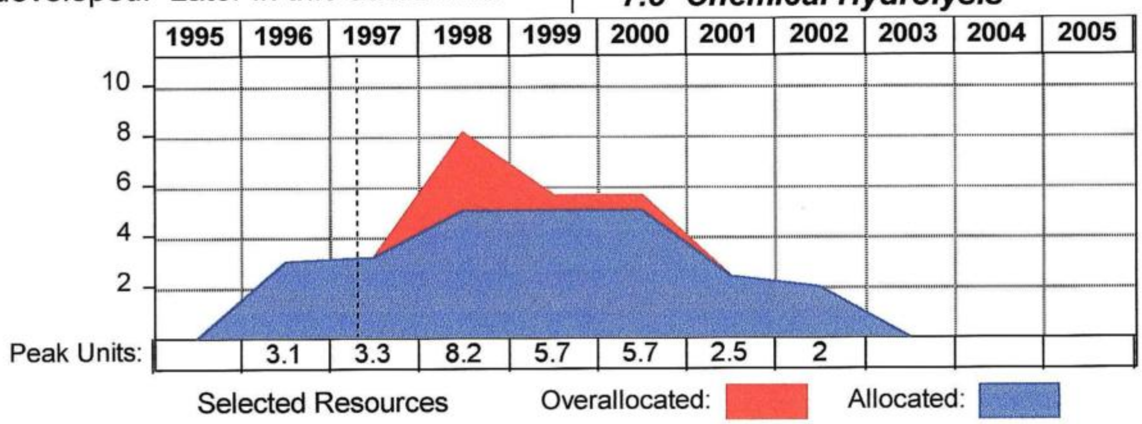


Figure 14 Resource Allocation for Chemical Hydrolysis Research

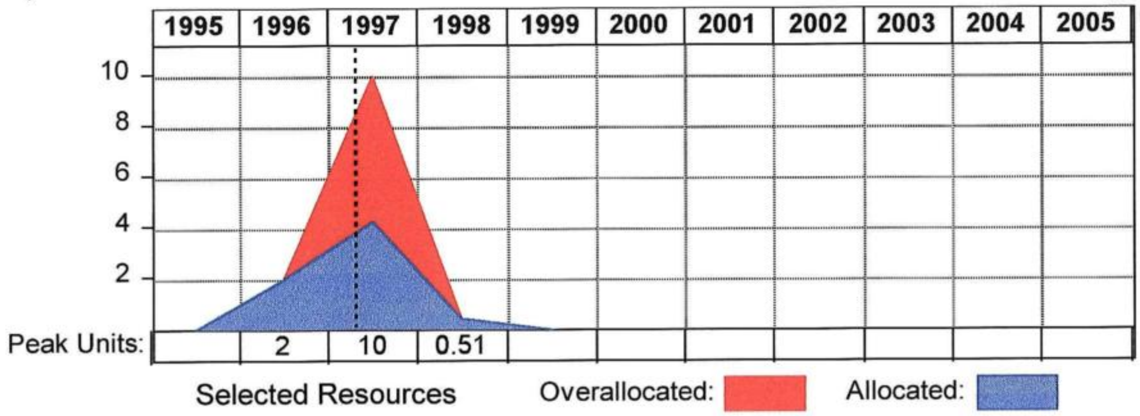


Figure 15 Resource Allocation for Softwoods Research

Resource Analysis

Figure 14 shows the resource graph for hydrolysis research. This research shows a major spike in resource demand in FY 1998, resulting in a 60% overallocation of resources. Again, this does not mean that this overallocation will occur. It simply means that this year's assignments do not accommodate for the demand in this area for next year.

7.6 Softwoods Research Resource Analysis

Figure 15 shows the resource graph for softwoods research. The plan as outlined in the MYTP for softwoods is clearly unrealistic based on current resource assignments. The plan overallocates resources by more than 100% in 1997. This is clearly an area that must be looked at more closely in order to determine if the schedule and scope we have set for deployment of softwoods can be met without major revisions to resource assignments.

7.7 Pilot Plant Researchers

Figure 16 shows the resource graph for pilot plant research. Except for a spike in demand for this year, available resources seem in line with

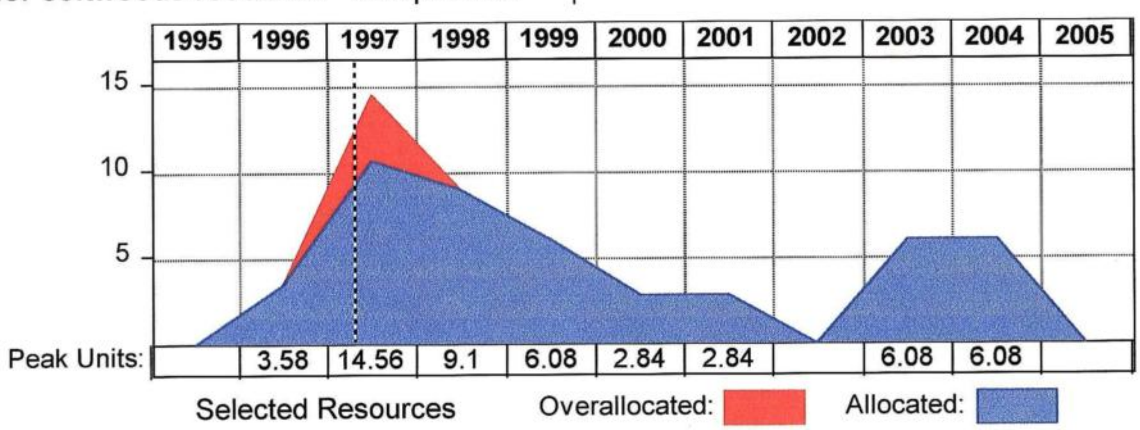


Figure 16 Resource Allocation for Pilot Plant Research

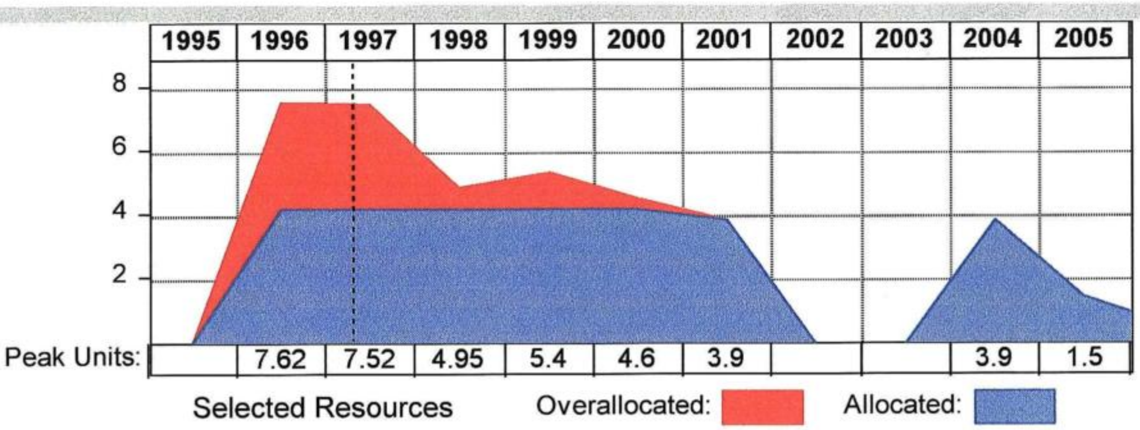


Figure 17 Resource Allocation for Partnership Activities

demands for the plan.

7.8 Partnership Development

Figure 17 shows resources for commercial partner-related resources. Partnership activities are overallocated in FY 1996 and FY 1997.

7.9 Process Development Researchers

Figure 18 shows the resource graph for process development work. Once again, this resource is overallocated by roughly 100% for the first three years of the plan. This is a major concern that should be addressed.

7.10 Analysis of Total Resources

Figure 19 shows the cumulative resource needs for all of the areas described in the previous sections. Remember that this analysis does not include feedstock or lignin research allocation analyses. In these cases , resource needs are calculated, but cannot be compared to current resource numbers because we were unable to pull these numbers together in time for

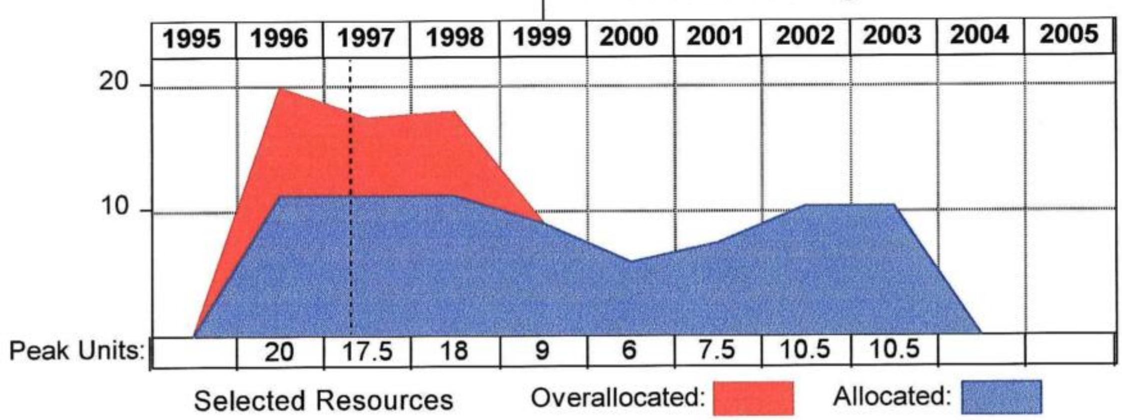


Figure 18 Resource Allocation for Process Development

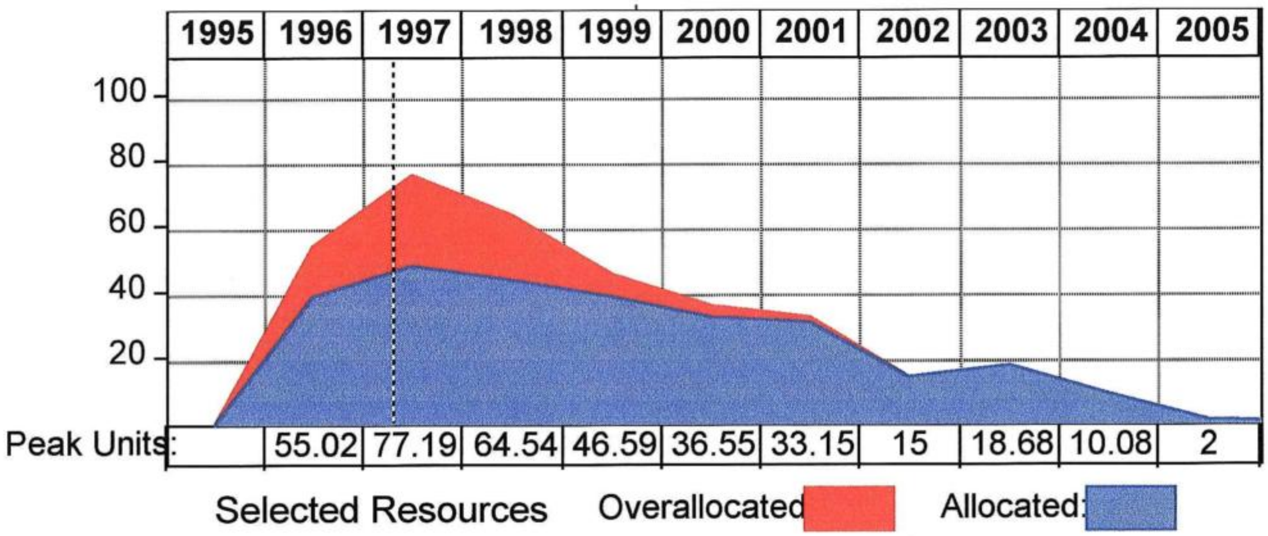


Figure 19 Resource Allocation for All Areas

the plan. The cumulative resources for which resource assignment data were available shows that the current plan will remain overallocated until the year 2000. The worse part of this is in the 1997 and 1998 time frame. It is in these two years that all development work must be completed in order to meet the year 2000 target for deployment. Furthermore, these two years show a worse overallocation because we are better able to forecast costs in the next two years than we are beyond that point. In other words, the outyears are also likely to be highly overallocated because we have underestimated resource needs. Figure 21 and Figure 20 show the resource allocations for these two areas. Note that they do not show any overallocations because we forced the number of maximum resource units to be greater than the peak demand for the plan.

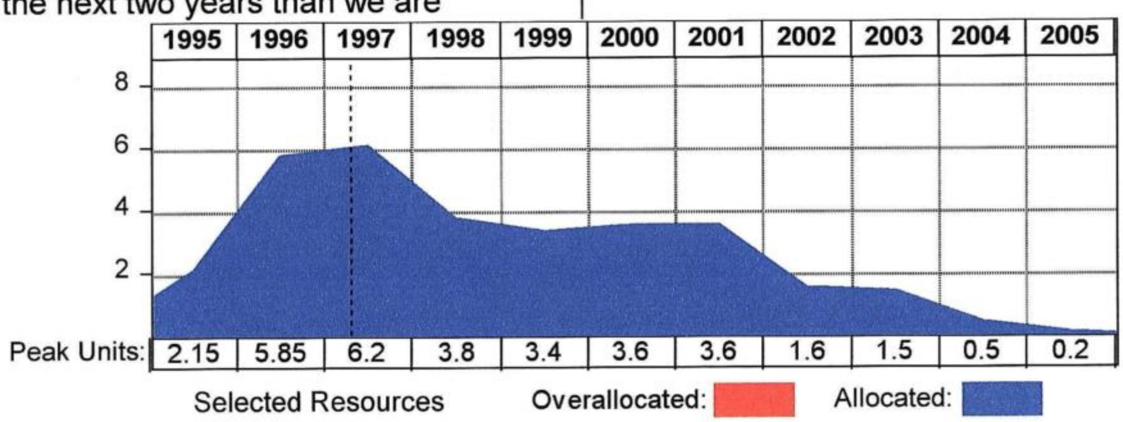


Figure 20 Resource Allocation for Feedstock Research

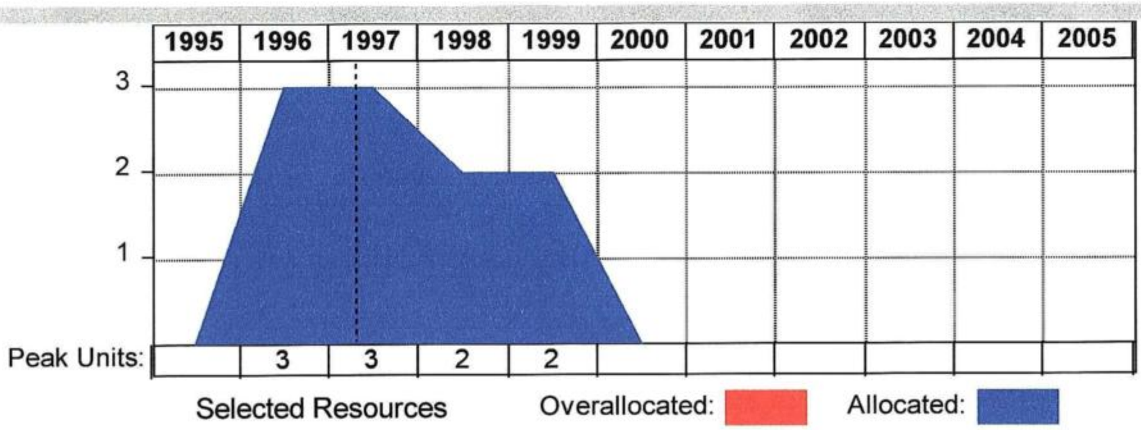


Figure 21 Resource Allocation for Lignin Research

8. Resource-Leveling the Plan

The plan described in Section 5 is, as we have already indicated, not resource-leveled. While the logic and sequence of the work to be done is not affected by resource leveling, the actual timing and duration of activities is greatly impacted when resource availability is considered.

The Gantt chart entitled "Ethanol Multi-Year Technical Plan: Resource-Leveled Plan Versus Baseline Plan" shows what happens to the schedule of activities for the program when current resource assignments are used to drive the timing of all activities. The blue bars on the chart reflect the new resource-leveled version of the plan, while the gray bars reflect the baseline plan before resources were used to drive the plan.

8.1 How Microsoft Project™ Resolves Resource Allocations

Microsoft Project™ preserves all finish-to-start relationships and all date constraints. When it identifies an overallocated resource, it begins delaying tasks until that overallocation is eliminated. This is not necessarily the best approach to use in resetting the schedule. Still, using this automated resource leveling approach is the most "objective" way to get a feeling for the impacts of resource limitations on the schedule of the program. In our case, the automatic resource leveling done by the software suggest substantial delays in program milestones related to overallocated resources.

8.2 The Impact of Resource Limitations on Near-Term Goals

Resource-leveling produces a three and one-half year delay in the year 2000 deployment goal. Our baseline plan had deployment of waste cellulose-to-ethanol technology from the first quarter of 2001 to the third quarter of 2004.

Resources for supporting the near term goal are, as already shown, severely bottlenecked. The main culprit in preventing execution of our near term goal is process development. As we shall show later in this report, process integration activities are on the critical path for completion of the near term goal. Given the almost 100% overallocation of resources for process development in this plan, it is clear that it is this area of the program that has contributed the most to the potential delays predicted by Microsoft Project™.

8.3 The Impact of Resource Limitations on Mid Term Goals

The severity of schedule delays becomes slightly less for the mid term. This is probably due to a combination of underestimated resources for the mid term and a genuinely reduced bottleneck in resources supporting the mid term goal. Deployment of switchgrass technology moves from the end of

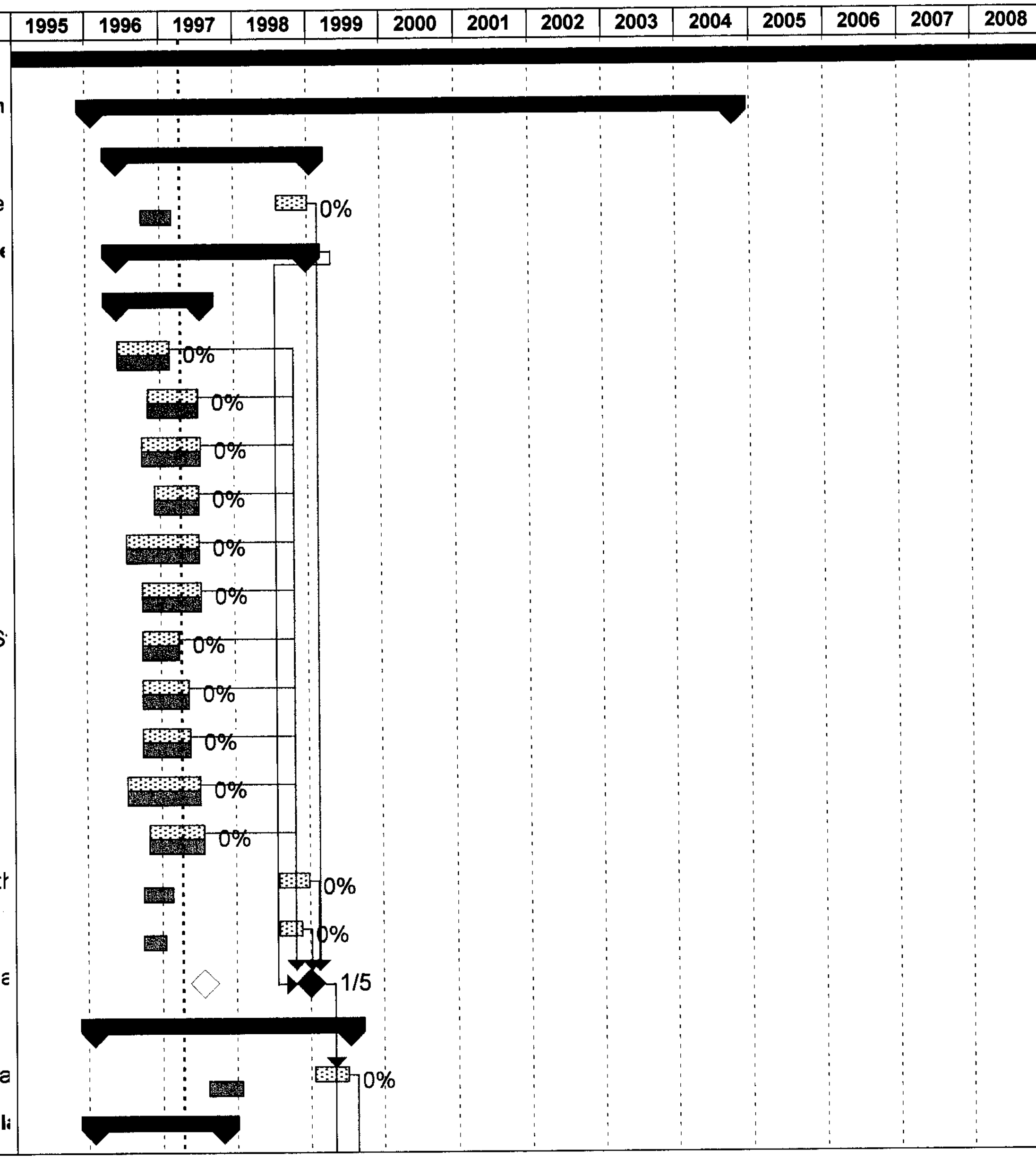
2005 to the 2008. This is probably due to the “rolling wave” of delays that occur as a result of pushing out activities for the near term technology deployment.

Figure 22: Ethanol Multi-Year Technical Plan: Resource-Leveled Plan Versus Baseline Plan (Bioethanol Program v24 Level)

Shown on next 20 pages

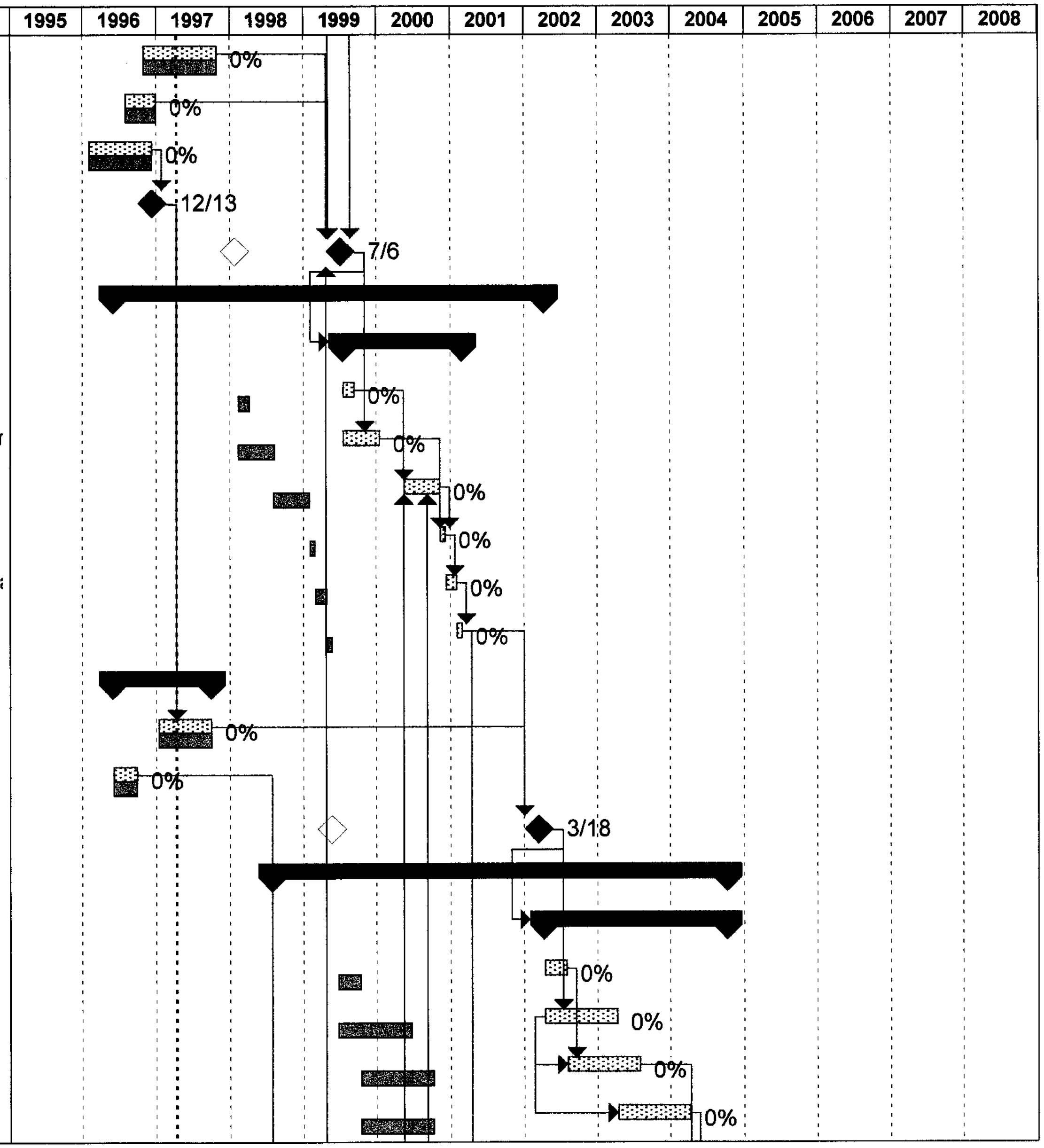
Ethanol Multi-Year Technical Plan
Resource-Leveled Plan Versus Baseline Plan
Bioethanol Program Plan v24 level

ID	WBS	Task Name
	0	**Bioethanol Program Plan v24 level**
1	1	**Commercially demonstrate waste biomass to ethanol techn**
2	1.1	**Preliminary Feasibility Studies**
3	1.1.1	Conduct New Preliminary Feasibility Studies (supporte
4	1.1.2	**Complete Existing Preliminary Feasibility Studies (supporte**
5	1.1.2.1	**Near term softwood opportunities**
6	1.1.2.1.1	Quincy Library Group Feasibility Study (softwood)
7	1.1.2.1.2	Colorado "Pine Zone" Feasibility Study (softwood)
8	1.1.2.1.3	2 contracts (TBD)
9	1.1.2.1.4	PALCO and LP Feasibility Studies (softwood)
10	1.1.2.1.5	IBI CRADA (softwood)
11	1.1.2.1.6	CARB Bioethanol Life Cycle Analysis (softwood)
12	1.1.2.1.7	Washington State Energy Office Pulp Mill Feasibility S
13	1.1.2.2	ACE Feasibility Study (CRP grass)
14	1.1.2.3	Iowa Feasibility Study (CRP grass)
15	1.1.2.4	Delta-T CRADA (feedstock to be determined)
16	1.1.2.5	Cellulase Partnership with Iogen
17	1.1.2.6	Quaker Oats Chemicals/Manildra Feasibility Study (otl
18	1.1.2.7	Pure Vision Feasibility Study (other feedstock)
19	1.1.3	Select Partners for Final Feasibility Studies (apply Fina
20	1.2	**Final Feasibility Studies**
21	1.2.1	Conduct New Final Feasibility Studies (supported by la
22	1.2.2	**Complete Existing Final Feasibility Studies (supported by la**



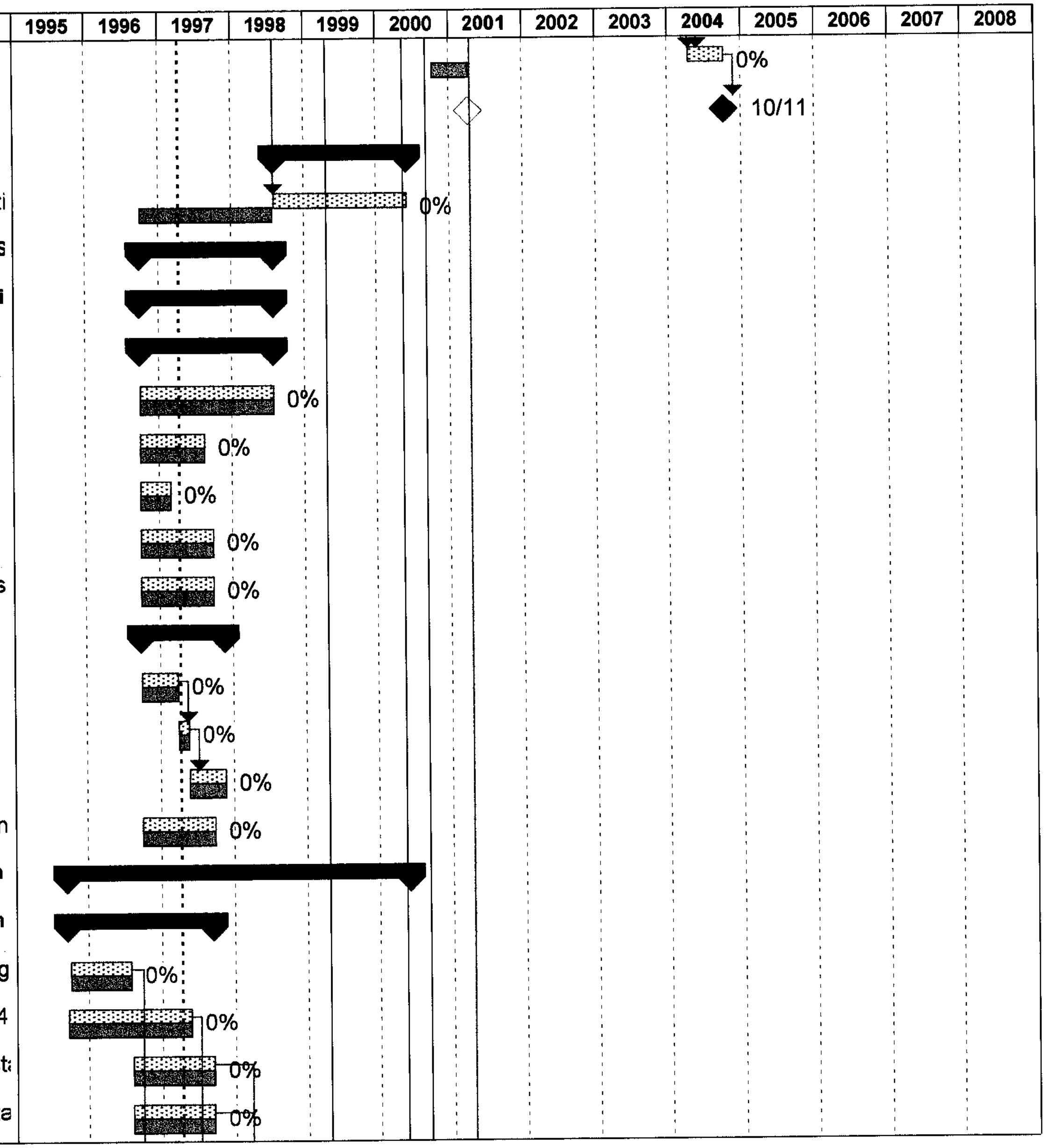
Ethanol Multi-Year Technical Plan
Resource-Leveled Plan Versus Baseline Plan
Bioethanol Program Plan v24 level

ID	WBS	Task Name
23	1.2.2.1	Coors CRADA Phase 2 (grain milling residue)
24	1.2.2.2	New Energy CRADA (grain milling residue)
25	1.2.2.3	Gridley Project Phase 1 (rice straw)
26	1.2.2.4	Gridley Phase 2 Go/No-go Decision
27	1.2.3	Select Partners for Business Plan Development (apply
28	**1.3**	**Business Plans**
29	**1.3.1**	**Conduct New Business Plans**
30	1.3.1.1	Negotiate Legal Arrangements with Partners
31	1.3.1.2	Establish Feedstock/Product Contracts and Site Comm
32	1.3.1.3	Conduct PDU Testing and Data Analysis
33	1.3.1.4	Re-evaluate Process Design and Cost Estimate
34	1.3.1.5	Negotiate License Agreements and Performance Guar
35	1.3.1.6	Issue New Business Plans
36	**1.3.2**	**Complete Existing Business Plans**
37	1.3.2.1	Gridley Phase 2 - issue business plan
38	1.3.2.2	Amoco CRADA Phase 3
39	1.3.3	Select Partners for Demonstration Plant Development
40	**1.4**	**Demonstration Plants**
41	**1.4.1**	**Conduct New Demonstration Plant Efforts**
42	1.4.1.1	Finance Facility
43	1.4.1.2	Conduct Detailed Design
44	1.4.1.3	Obtain Permits
45	1.4.1.4	Construct Facility



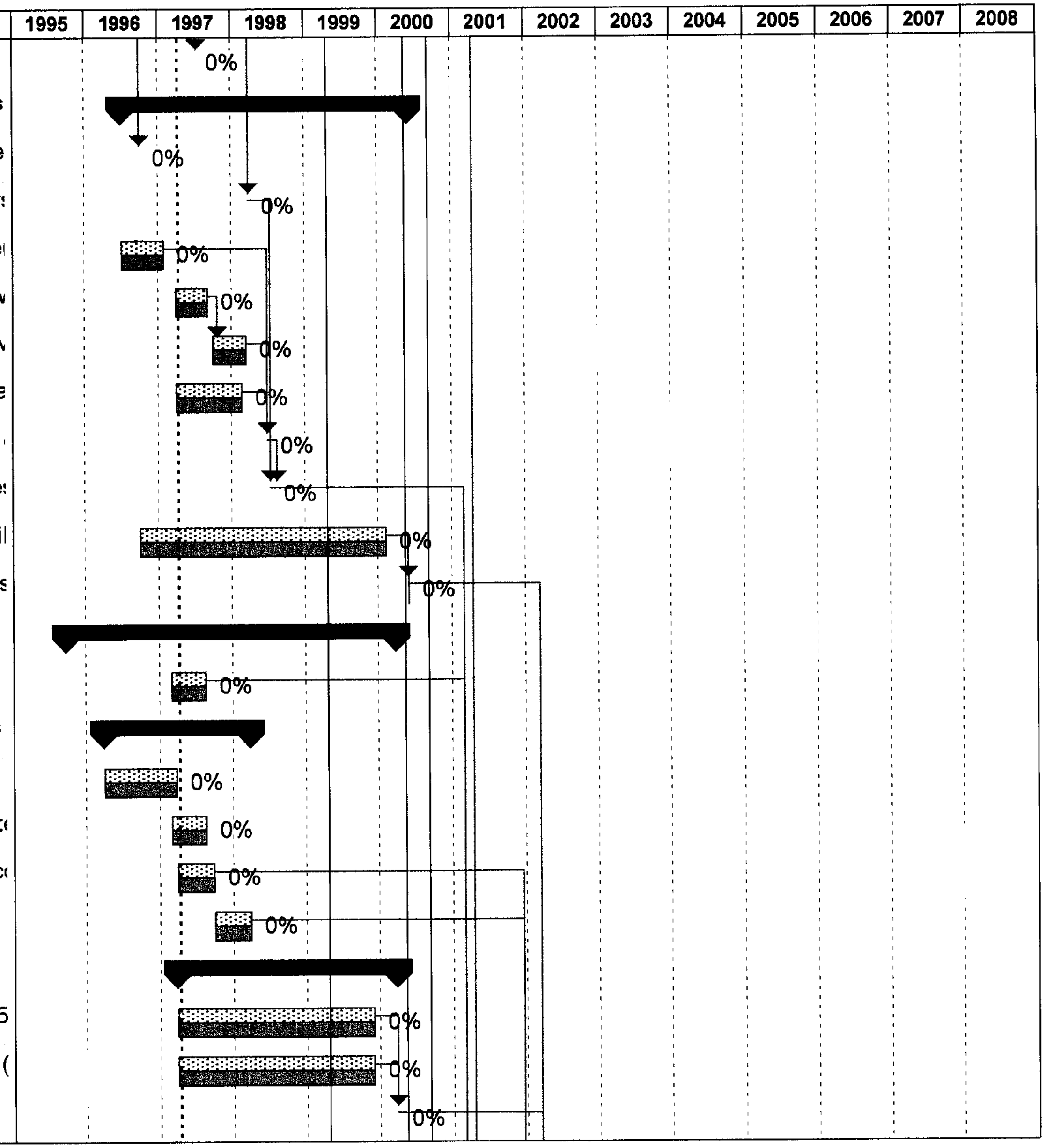
Ethanol Multi-Year Technical Plan
Resource-Leveled Plan Versus Baseline Plan
Bioethanol Program Plan v24 level

ID	WBS	Task Name
46	1.4.1.5	Start Up Facility by Year 2000
47	1.4.1.6	Commercial Operation
48	**1.4.2**	**Complete Existing Demonstration Plant Efforts**
49	1.4.2.1	Amoco CRADA Phase 4 - Final Report on Demonstrati
50	**2**	**Develop and Maintain PDT Capabilities and Data Bases to S**
51	**2.1**	**PDT Tools, Data Bases and Capabilities to Conduct Feasibi**
52	**2.1.1**	**Develop Data Base for Near-Term Feedstock**
53	2.1.1.1	Develop Forest Residue GIS Database
54	2.1.1.2	Develop Saw & Pulp Mill GIS Database
55	2.1.1.3	Montana State Wood Waste Assessment
56	2.1.2	Maintain PDT Engineering/Economic Analysis Models
57	2.2	Develop Data Base for Sources of Funding to Partners
58	**3**	**Establish Partnerships for Long-Term Research**
59	3.1	Determine Key Long-Term Research Objectives
60	3.2	Determine Who Should Conduct Research to Achieve
61	3.3	Establish Partnerships with Non-NREL Entities
62	4	Coordinate With Federal, State, Local & Private Organ
63	**5**	**Develop Switchgrass Partnerships for Ethanol Production**
64	**5.1**	**Identify potential locations for crop supplies at $42/dry ton**
65	5.1.1	Complete crop economic baselines at national and reg
66	5.1.2	Complete integrated GIS analysis in selected states (4
67	5.1.3	Complete Integrated GIS analysis of potential in 14 st:
68	5.1.4	Complete preliminary waste and feedstock supply data



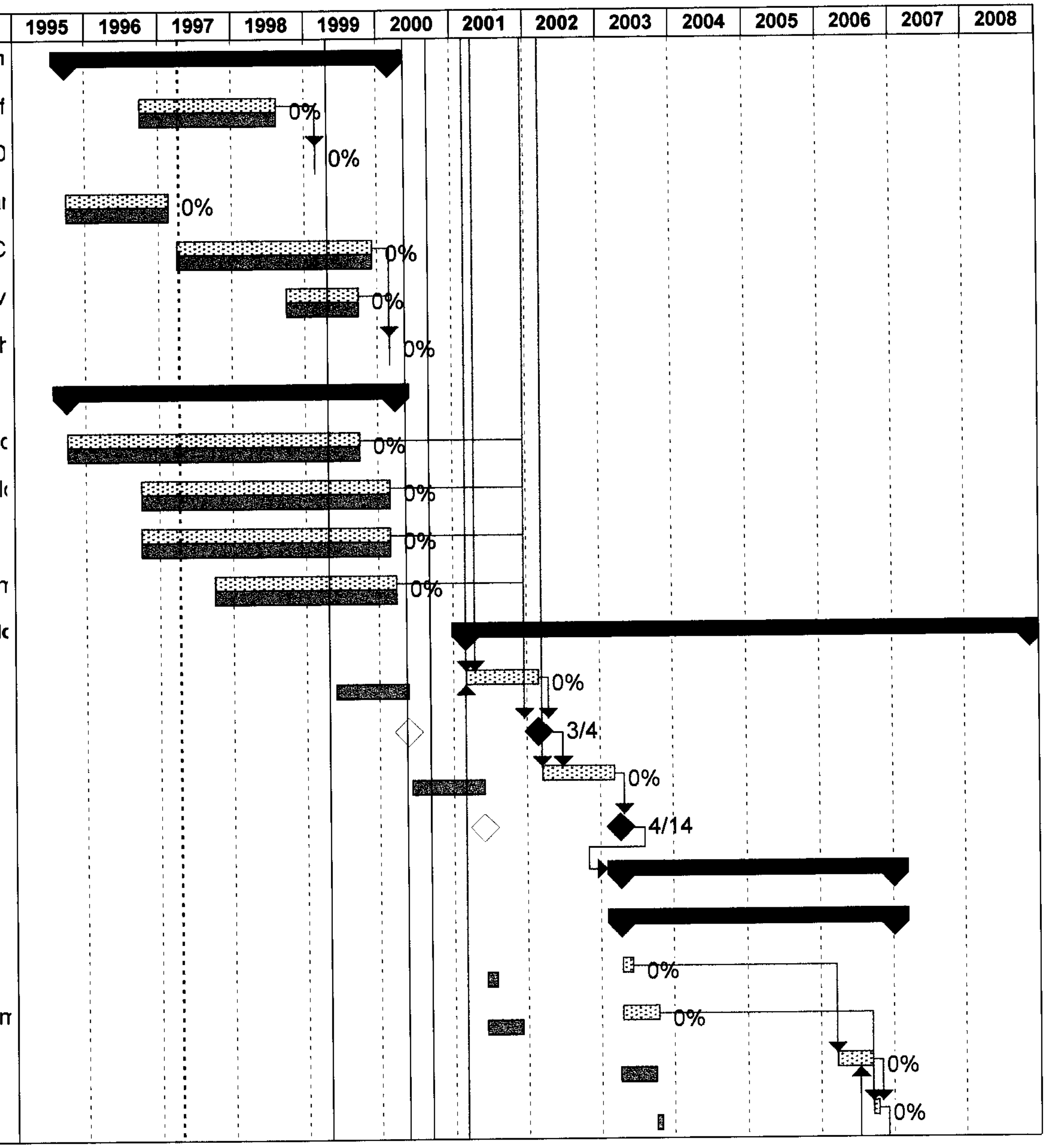
Ethanol Multi-Year Technical Plan
Resource-Leveled Plan Versus Baseline Plan
Bioethanol Program Plan v24 level

ID	WBS	Task Name
69	5.1.5	Recommend locations for focused R&D, scale-up and
70	**5.2**	**Assist feasibility studies with integrated analysis products**
71	5.2.1	Provide integrated crop economic models for develope
72	5.2.2	Provide results of GIS model runs to states, developer:
73	5.2.3	Provide feedstock supply curves for ethanol market pe
74	5.2.4	Collaborate with USDA on putting switchgrass & SRW
75	5.2.5	Use USDA models for improving feedstock supply curv
76	5.2.6	Integrate cost & production risks in farmer decision ma
77	5.2.7	Publish crop supply models and scenario results (4.01
78	5.2.8	Recommend locations for preliminary feasibility studie:
79	5.2.9	Update crop economic info as new data becomes avail
80	5.2.10	Release updated crop economic models for developers
81	**5.3**	**Expand switchgrass supply system expertise & interest**
82	5.3.1	Summarize and publish results of first 5 yrs SG R&D
83	**5.3.2**	**Expand number and scale of switchgrass testing locations**
84	5.3.2.1	Farmer participation in Chariton Valley, Iowa secured
85	5.3.2.2	Renegotiate Univ. contracts to include scale-ups & sat
86	5.3.2.3	Negotiate extending variety testing & breeding to Wisc
87	5.3.2.4	USDA Plant Materials Center Participation Secured
88	**5.3.3**	**Predict switchgrass market potential for feasibility studies**
89	5.3.3.1	Link ISU economics experts with Chariton RC&D (5.05
90	5.3.3.2	Link ag economics expertise with other scale-up sites (
91	5.3.3.3	Provide economic info for final feasibility studies



Ethanol Multi-Year Technical Plan
Resource-Leveled Plan Versus Baseline Plan
Bioethanol Program Plan v24 level

ID	WBS	Task Name
92	**5.3.4**	**Predict environmental effects of switchgrass supply systen**
93	5.3.4.1	Develop models for national/regional environmental eff
94	5.3.4.2	Model & predict regional level water quality effects (4.0
95	5.3.4.3	Collect & evaluate info on soil nutrient and carbon chai
96	5.3.4.4	Model erosion and water quality effects in Iowa (CVRC
97	5.3.4.5	Compare SG & alt. crop environmental effects from av
98	5.3.4.6	Publish preliminary predictions of env. effects of switch
99	**5.3.5**	**Stimulate producer interest in business plan development**
100	5.3.5.1	Develop farmer oriented news outlets, hold news broac
101	5.3.5.2	Conduct field days and workshops for farmers & devel
102	5.3.5.3	Develop networks with farmers and developers (5.0)
103	5.3.5.4	Educate public, developers, policy makers on environn
104	**6**	**Commercially demonstrate switchgrass to ethanol technolc**
105	6.1	Preliminary feasibility studies
106	6.2	Select partners for final feasibility studies
107	6.3	Final feasibility studies
108	6.4	Select partners for business plan development
109	**6.5**	**Business Plans**
110	**6.5.1**	**Conduct New Business Plans**
111	6.5.1.1	Negotiate Legal Arrangements with Partners
112	6.5.1.2	Establish Feedstock/Product Contracts and Site Comn
113	6.5.1.3	Conduct PDU Testing and Data Analysis
114	6.5.1.4	Re-evaluate Process Design and Cost Estimate



Ethanol Multi-Year Technical Plan
Resource-Leveled Plan Versus Baseline Plan
Bioethanol Program Plan v24 level

ID	WBS	Task Name
115	6.5.1.5	Negotiate License Agreements and Performance Guar:
116	6.5.1.6	Issue New Business Plans
117	6.6	Select Partners for Demonstration Plant Development
118	**6.7**	**Demonstration Plants**
119	**6.7.1**	**Agricultural Production**
120	6.7.1.1	Establish Feedstock Supply Contracts & Financing
121	6.7.1.2	Fall site preparation & secure seed
122	6.7.1.3	Spring site preparation & planting
123	6.7.1.4	First year harvest (stored for start-up runs)
124	6.7.1.5	Evaluate supply & contract for wastes if necessary
125	6.7.1.6	Second year harvest;pre-commercial start-up
126	**6.7.2**	**Conduct New Demonstration Plant Efforts**
127	6.7.2.1	Finance Facility
128	6.7.2.2	Conduct Detailed Design
129	6.7.2.3	Obtain Permits
130	6.7.2.4	Construct Facility
131	6.7.2.5	Start Up Facility by Year 2005
132	6.7.2.6	Commercial Operation
133	**7**	**Core Technology Development**
134	**7.1**	**Switchgrass Feedstock Production Technology**
135	**7.1.1**	**Support Switchgrass Crop Development Centers in at least**
136	**7.1.1.1**	**Identify best varieties and yield potential**
137	**7.1.1.1.1**	**Screen for best varieties in South & Mid-Atlantic States**

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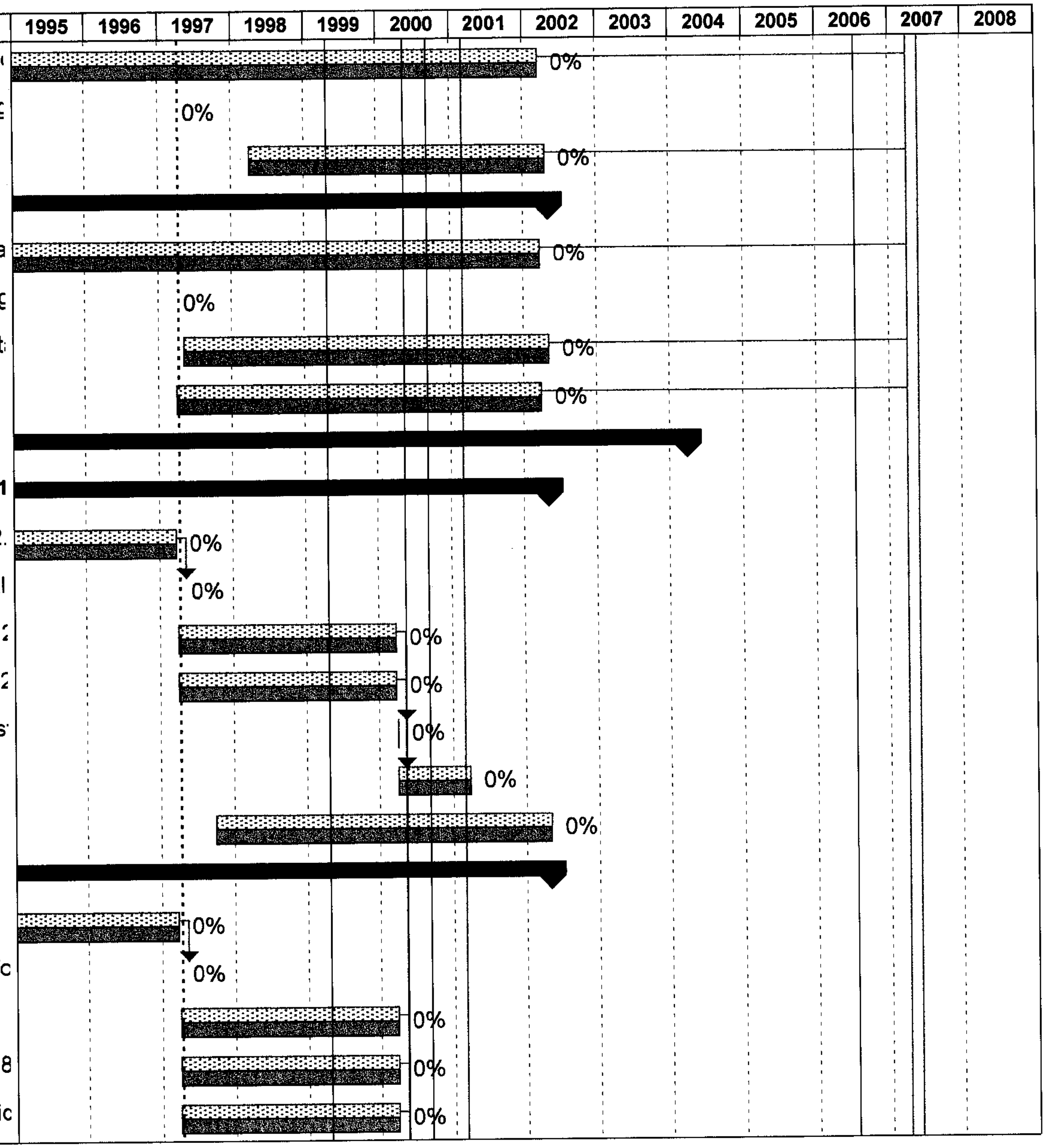
ID	WBS	Task Name
138	7.1.1.1.1.1	Screen available varieties at 19 sites for high& sustain
139	7.1.1.1.1.2	Recommend best varieties for first scale-up & breeding
140	7.1.1.1.1.3	Expand variety screening to 13 other states
141	**7.1.1.1.2**	**Screen for best varieties & locations in NC & NE/L states**
142	7.1.1.1.2.1	Screen available varieties in Nebraska for high & susta
143	7.1.1.1.2.2	Recommend best varieties for first scale-up & breeding
144	7.1.1.1.2.3	Screen available varieties in Wisconsin for high & sust
145	7.1.1.1.2.4	Expand variety screening to 10 other states
146	**7.1.1.2**	**Optimize culture to improve yields & benefit environment**
147	**7.1.1.2.1**	**Test culture effects in Southern & Mid-Atl. experiments 1-1**
148	7.1.1.2.1.1	Identify establishment & fertilizer requirements (2.02,2.
149	7.1.1.2.1.2	Provide preliminary crop mgm guidelines for R&D scal
150	7.1.1.2.1.3	Identify nutrient factors affecting yield & quality (2.02, 2
151	7.1.1.2.1.4	Identify harvest factors affecting yield & quality (2.02, 2
152	7.1.1.2.1.5	Provide improved crop mgm guidelines for feasibility s
153	7.1.1.2.1.6	Use data to improve econ., env, and supply models
154	7.1.1.2.1.7	Repeat above in 13 other states with extension links
155	**7.1.1.2.2**	**Test culture effects in NC experiments 1-10 acre**
156	7.1.1.2.2.1	Identify establishment & fertilizer requirements (2.07)
157	7.1.1.2.2.2	Provide preliminary crop mgm guidelines to growers fc
158	7.1.1.2.2.3	Identify nutrient factors affecting yield & quality (2.08)
159	7.1.1.2.2.4	Identify harvest factors affecting yield and quality (2.08
160	7.1.1.2.2.5	Develop information necessary to register new herbicic



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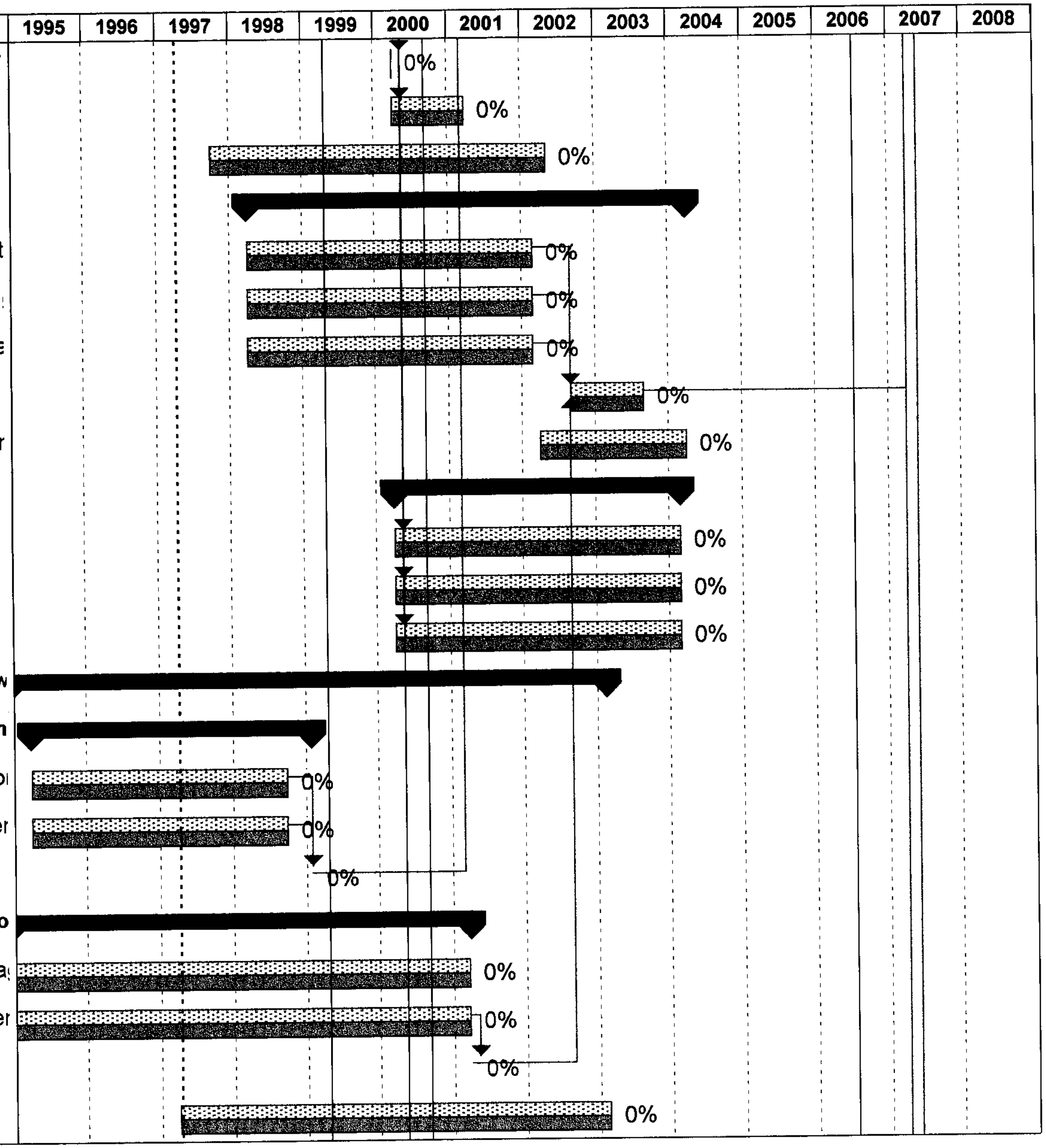
ID	WBS	Task Name
161	7.1.1.2.2.6	Provide improved crop mgm guidelines for feasibility s
162	7.1.1.2.2.7	Use data to improve econ., env., and supply models
163	7.1.1.2.2.8	Repeat above in 13 other states with extension links
164	**7.1.1.2.3**	**Improve culture through understanding mechanisms**
165	7.1.1.2.3.1	Develop mechanistic understanding of yield response t
166	7.1.1.2.3.2	Develop mechanistic understanding of responses to m
167	7.1.1.2.3.3	Develop information on value of ash & wastes as soil a
168	7.1.1.2.3.4	Use information to improve culture guidelines
169	7.1.1.2.3.5	Use information to improve national feedstock supply r
170	**7.1.1.2.4**	**Adapt culture to potential locations for commercial demos**
171	7.1.1.2.4.1	Identify best establishment techniques for locations
172	7.1.1.2.4.2	Test range of fertilizer levels & methods of appl.
173	7.1.1.2.4.3	Test herbicide types, rates, & appl. methods
174	**7.1.1.3**	**Evaluate environmental effects of culture techniques at few**
175	**7.1.1.3.1**	**Develop SE management options for environmentally soun**
176	7.1.1.3.1.1	Evaluate surface & subsurface water quality as functio
177	7.1.1.3.1.2	Evaluate soil quality responses as function of manager
178	7.1.1.3.1.3	Provide site mgm/env guidelines to growers & EPA
179	**7.1.1.3.2**	**Develop NC site management options for environmental so**
180	7.1.1.3.2.1	Evaluate subsurface water quality as function of mana
181	7.1.1.3.2.2	Evaluate soil quality responses as function of manager
182	7.1.1.3.2.3	Provide site mgm/env. guidelines to growers & EPA
183	7.1.1.3.3	Educate multiple groups on environmental benefits



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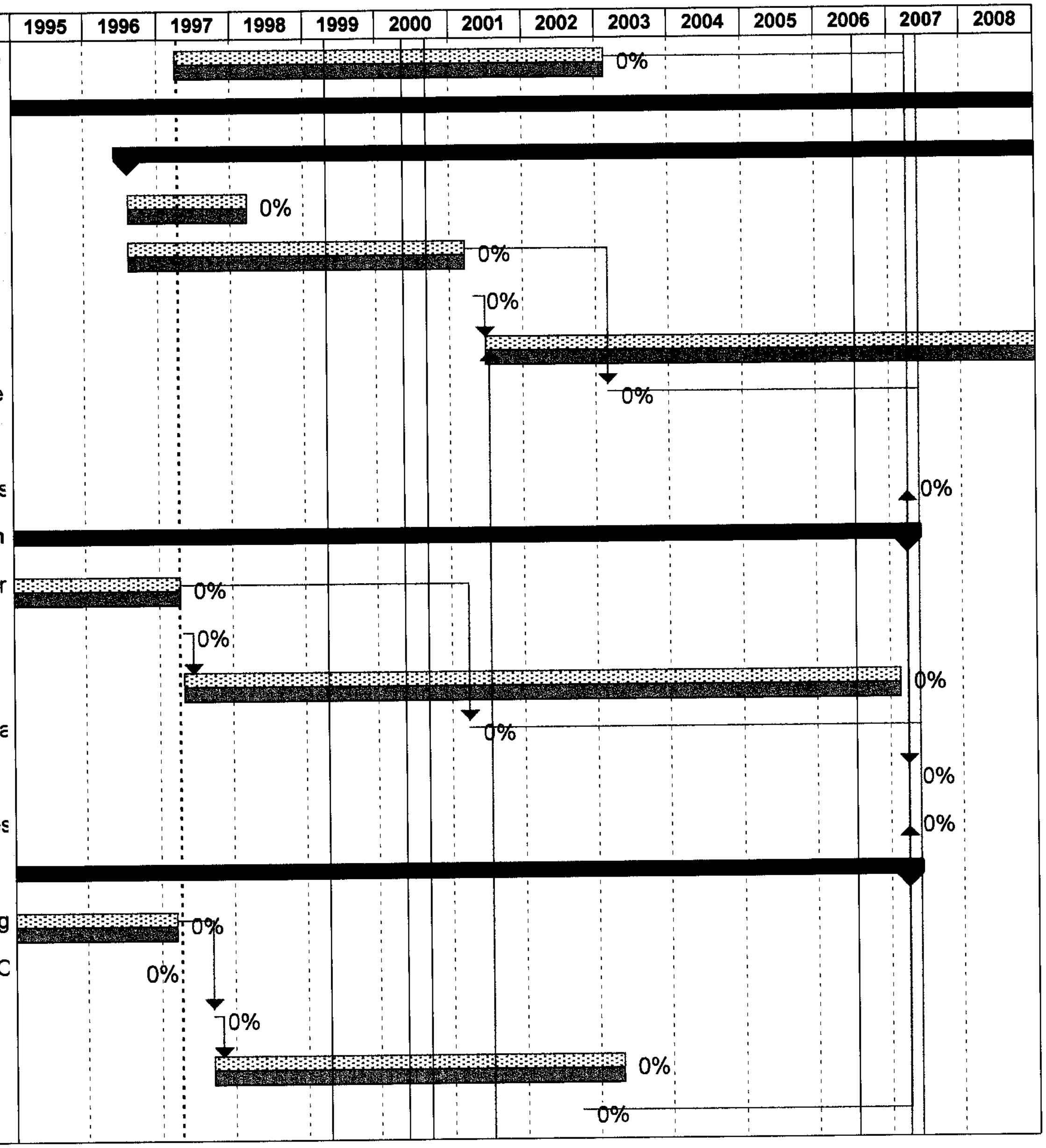
ID	WBS	Task Name
184	7.1.1.3.4	Integrate culture research results into analysis & guide
185	**7.1.1.4**	**Improve yields through breeding and testing**
186	**7.1.1.4.1**	**Improve SE yields through breeding & testing (2.09)**
187	7.1.1.4.1.1	Germplasm collection
188	7.1.1.4.1.2	Round 1 breeding, yield screening & regional testing
189	7.1.1.4.1.3	Evaluate progress to date; modify breeding strategy
190	7.1.1.4.1.4	Round 2 breeding, screening, regional testing
191	7.1.1.4.1.5	first new biomass SE varieties released for large-scale
192	7.1.1.4.1.6	additional new varieties released to seed companies
193	7.1.1.4.1.7	Hand-off breeding to other agencies/private companies
194	**7.1.1.4.2**	**Improve SC yields through breeding & testing in SC region**
195	7.1.1.4.2.1	Round 1 breeding, screening & regional testing in SC r
196	7.1.1.4.2.2	Evaluate progress; modify breeding strategy
197	7.1.1.4.2.3	Round 2 breeding, screening, regional testing
198	7.1.1.4.2.4	first new SC biomass varieties released to seed compa
199	7.1.1.4.2.5	additional new varieties released to seed companies
200	7.1.1.4.2.6	Hand-off breeding to other agencies/private companies
201	**7.1.1.4.3**	**Improve NC yields through breeding & testing (2.07)**
202	7.1.1.4.3.1	Round 1 breeding, biomass screening, regional testing
203	7.1.1.4.3.2	1 new improved forage/biomass variety released in NC
204	7.1.1.4.3.3	Evaluate progress; modify breeding strategy
205	7.1.1.4.3.4	Round 2 breeding, screening, regional testing
206	7.1.1.4.3.5	1-2 new varieties released to seed companies



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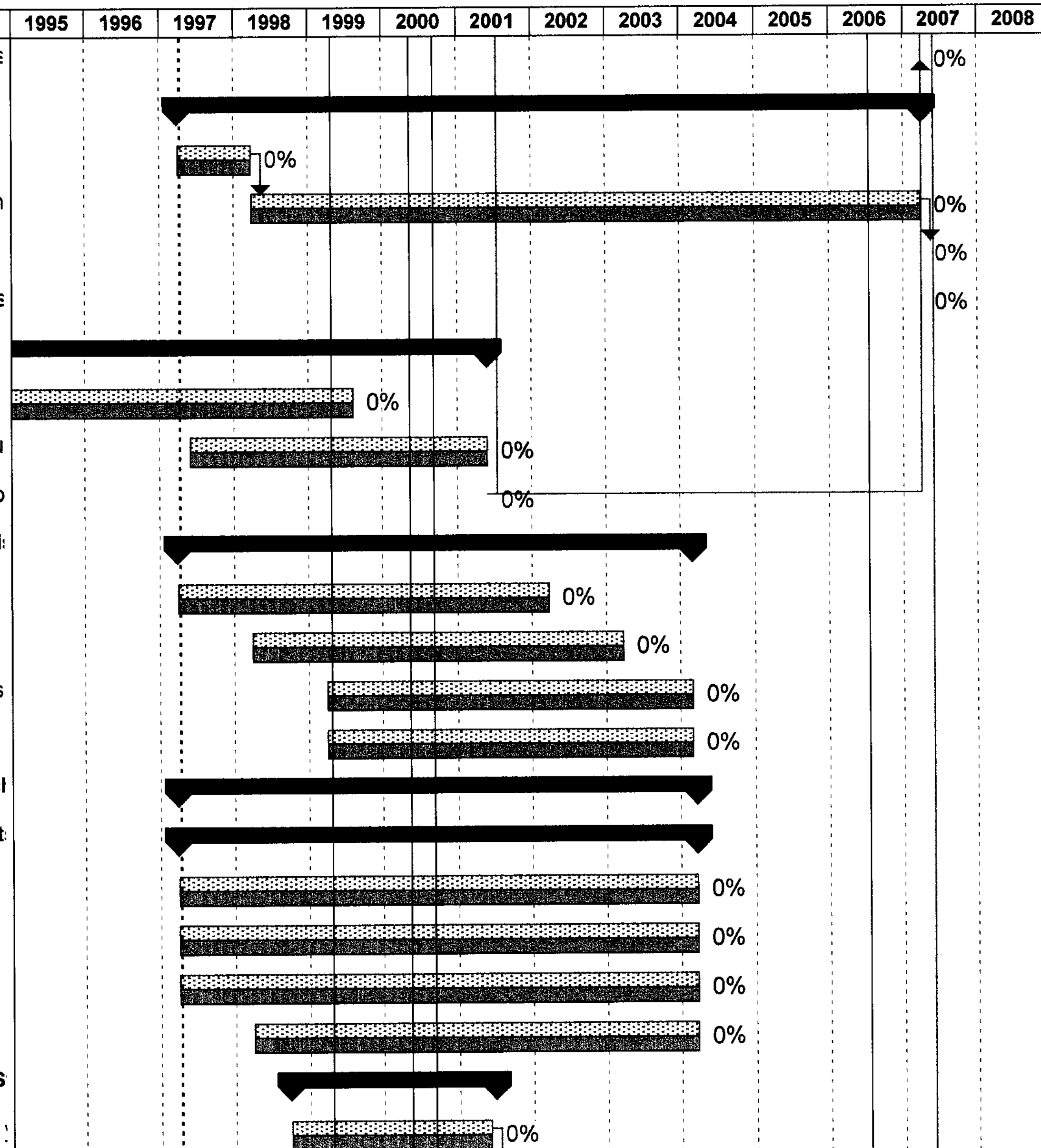
ID	WBS	Task Name
207	7.1.1.4.3.6	Hand-off breeding to other agencies/private companies
208	**7.1.1.4.4**	**Improve NE/Lake yields through breeding & testing (2.07)**
209	7.1.1.4.4.1	Germplasm collection
210	7.1.1.4.4.2	Round 1 breeding, yield screening & regional testing in
211	7.1.1.4.4.3	1-2 new varieties released in NE/L
212	7.1.1.4.4.4	Hand-off breeding to other agencies/private companies
213	**7.1.1.5**	**Develop physiology/biotechnology information**
214	7.1.1.5.1	Improve growth physiology understanding and links to
215	7.1.1.5.2	Develop enhanced breeding techniques based on tissu
216	7.1.1.5.3	Handoff information to breeding activities/private secto
217	**7.1.1.6**	**Assure sustainable yields by addressing pathogen & pest i**
218	7.1.1.6.1	Use Iowa scale-up to monitor pathogens and pests
219	7.1.1.6.2	Monitor pathogens &pests in all additional scale-ups
220	7.1.1.6.3	Evaluate control mechanisms for pathogens and pests
221	7.1.1.6.4	Include pathogen/pest resistance in breeding efforts
222	**7.1.2**	**Reduce risks & expand expertise through scale-up researcl**
223	**7.1.2.1**	**Expand number and scale of switchgrass field R&D project**
224	7.1.2.1.1	New plantings in Chariton Valley, Iowa (4000 acres)
225	7.1.2.1.2	New plantings in SC region (20-50 acres) (2.03)
226	7.1.2.1.3	New plantings in SE region (20-500 acres), (2.04)
227	7.1.2.1.4	New plantings in alternate region (20-50 acres)
228	**7.1.2.2**	**Improve Engineering of Switchgrass Harvest, Handling & S**
229	7.1.2.2.1	Test/modify existing large harvesters to handle higher



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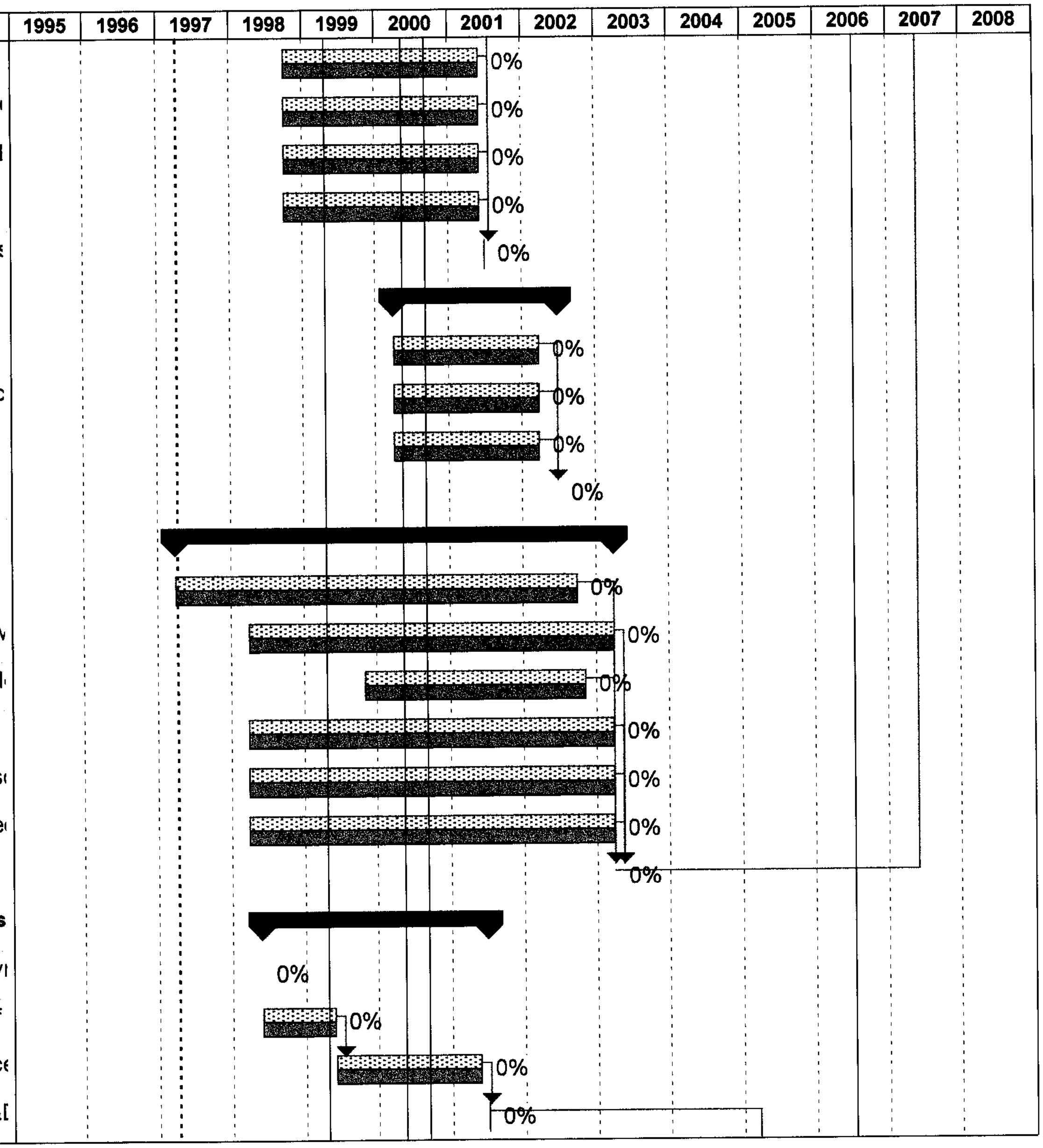
ID	WBS	Task Name
230	7.1.2.2.2	Test/modify existing small harvesters to handle higher
231	7.1.2.2.3	Identify best field storage & handling alternatives for N
232	7.1.2.2.4	Identify best field storage & handling alternatives for Sl
233	7.1.2.2.5	Identify transportation & size reduction options
234	7.1.2.2.6	Provide information to assist partnership arrangements
235	**7.1.2.3**	**Perform economic and risk studies with scale-up data**
236	7.1.2.3.1	Evaluate yield and production cost variation data
237	7.1.2.3.2	Evaluate storage, handling, transportation cost variatic
238	7.1.2.3.3	Evaluate financing and procurement strategies
239	7.1.2.3.4	Provide information to update business plans
240	**7.1.2.4**	**Monitor and document environmental effects**
241	7.1.2.4.1	Monitor soil quality changes across Iowa Scaleup
242	7.1.2.4.2	Document biodiversity and wildlife habitat effects in lov
243	7.1.2.4.3	Continue evaluating erosion & water quality effects in I
244	7.1.2.4.4	Monitor soil quality changes across second scale-up
245	7.1.2.4.5	Monitor regional level water quality effects of second s
246	7.1.2.4.6	Document biodiversity and wildlife habitat effects in se
247	7.1.2.4.7	Provide guidelines to demonstration project growers
248	**7.1.2.5**	**Establish switchgrass quality variation for ethanol convers**
249	7.1.2.5.1	Identify feedstock characteristics relevant to SSF enzy
250	7.1.2.5.2	Collect Samples from field trials representing range of
251	7.1.2.5.3	Analyze feedstock samples for effects on ethanol proc
252	7.1.2.5.4	Handoff information & samples to ethanol process R&I



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ID	WBS	Task Name	1995–2008
253	**7.2**	**Biomass Conversion Technology**	
254	**7.2.1**	**Softwood-specific process integration and process develo**	
255	**7.2.1.1**	**Preliminary Technology Analysis**	
256	**7.2.1.1.1**	**Investigate technologies**	
257	7.2.1.1.1.1	SO2 steam explosion	0%
258	7.2.1.1.1.2	Dilute acid hydrolysis	0%
259	7.2.1.1.1.3	Concentrated acid	0%
260	7.2.1.1.1.4	ACOS Organosolv process	0%
261	7.2.1.1.1.5	Enzyme production	0%
262	7.2.1.1.1.6	Fermentation/SHF/SSF	0%
263	7.2.1.1.1.7	Lignin utilization	0%
264	**7.2.1.1.2**	**Model 5 process options for softwoods**	
265	7.2.1.1.2.1	Complete process & economic model	0%
266	7.2.1.1.2.2	Option A	0%
267	7.2.1.1.2.3	Option B	0%
268	7.2.1.1.2.4	Option C	0%
269	7.2.1.1.2.5	Option D	0%
270	7.2.1.1.2.6	Option E	0%
271	7.2.1.1.3	Identify technology gaps	0%
272	**7.2.1.2**	**Fill Technology Gaps for Softwoods**	
273	7.2.1.2.1	Revise softwoods technology plan	0%
274	7.2.1.2.2	Subcontract or CRADA with UBC	0%
275	7.2.1.2.3	Subcontract #2	0%

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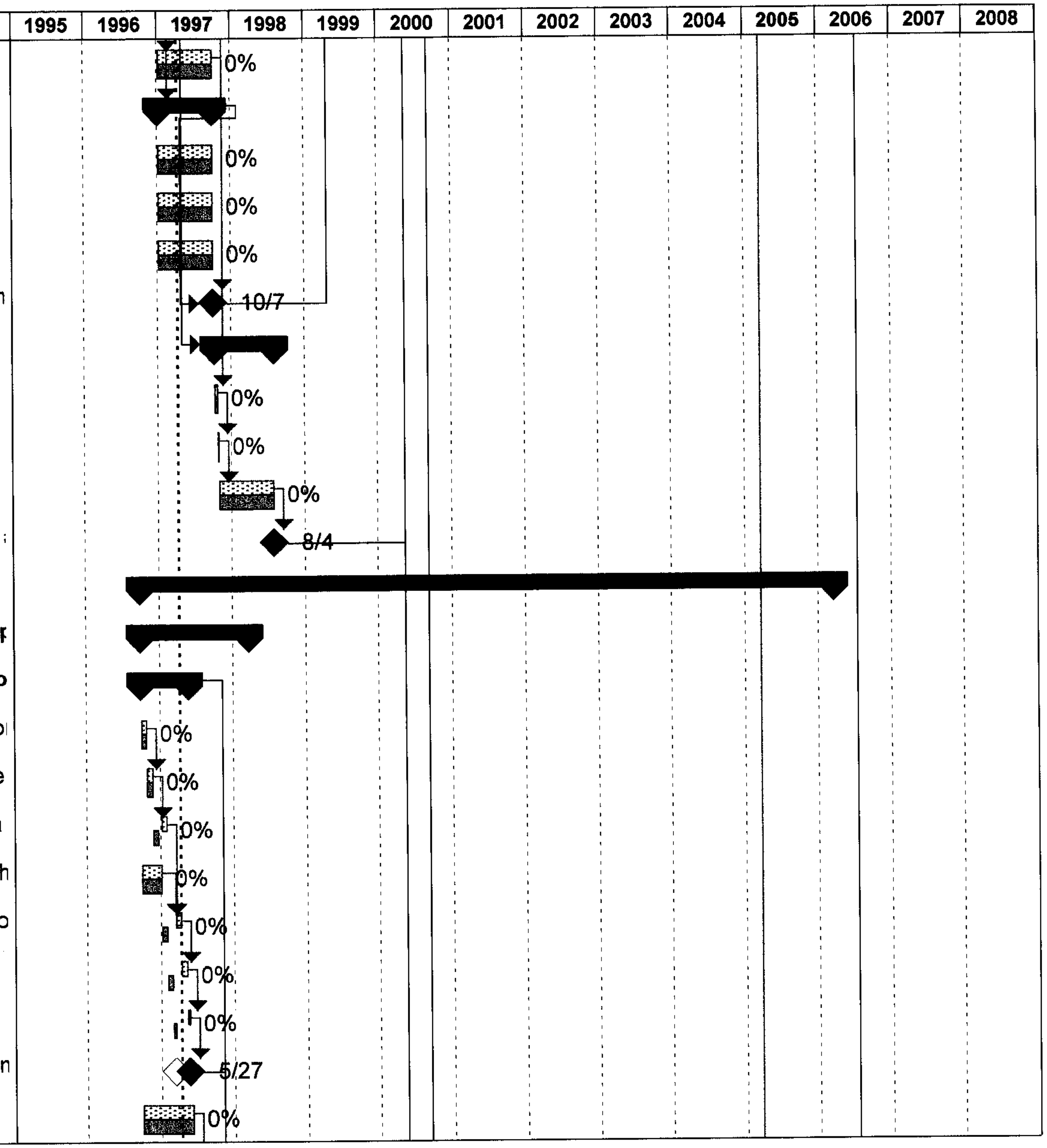
ID	WBS	Task Name
276	7.2.1.2.4	Subcontract #3
277	**7.2.1.2.5**	**Pretreatment & fermentation work at NREL**
278	7.2.1.2.5.1	Dilute acid pretreatment
279	7.2.1.2.5.2	SO2 Steam explosion
280	7.2.1.2.5.3	C6 Fermentation R&D
281	7.2.1.2.6	Preliminary assessment of integrated technologies con
282	**7.2.1.3**	**Process Selection and PDU Testing**
283	7.2.1.3.1	Revise Process Models
284	7.2.1.3.2	Select Process for further development
285	7.2.1.3.3	Subcontract #4
286	7.2.1.3.4	Integrated process for softwood to ethanol technology
287	**7.2.2**	**Process Integration and Process Development**
288	**7.2.2.1**	**Provide commercial development facility capabilities to sup**
289	**7.2.2.1.1**	**Demonstrate an integrated process for ethanol from cellulo**
290	7.2.2.1.1.1	Establish complete integrated process flow diagram fo
291	7.2.2.1.1.2	Prove that aseptic conditions can be maintained in the
292	7.2.2.1.1.3	Obtain approval to operate the mini-pilot plant using a
293	7.2.2.1.1.4	Design, procure and test ion exchange equipment for h
294	7.2.2.1.1.5	Ready Sunds reactor to produce pretreated sawdust fo
295	7.2.2.1.1.6	Run process qualifier technology demonstration
296	7.2.2.1.1.7	Document process qualifier demonstration
297	7.2.2.1.1.8	Mini-pilot biochemical conversion unit available for con
298	7.2.2.1.2	Design full pilot plant scale detoxification equipment



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ID	WBS	Task Name
299	7.2.2.1.3	Install full pilot plant scale detoxification equipment
300	7.2.2.1.4	Test and modify full pilot scale detoxification equipmer
301	7.2.2.1.5	Detoxification process available for pilot scale commer
302	7.2.2.1.6	Design SSCF system for pilot plant demonstration bas
303	7.2.2.1.7	Evaluate spent solids for combustion value
304	7.2.2.1.8	Investigate the impacts of gypsum on the bioethanol pı
305	7.2.2.1.9	Pilot scale testing capability available for use by comm
306	**7.2.2.2**	**Provide integrated process technology for commercial dev**
307	**7.2.2.2.1**	**Develop cellulase enzyme production technology utilizing I**
308	7.2.2.2.1.1	Establish cellulase production on hydrolysate and pretı
309	7.2.2.2.1.2	Improve cellulase production on hydrolysate and pretre
310	7.2.2.2.1.3	Cellulase enzyme production technology available for c
311	**7.2.2.2.2**	**Improve integrated process performance to achieve cost ta**
312	7.2.2.2.2.1	Produce pretreated and detoxified materials to meet te
313	7.2.2.2.2.2	Improve pretreatment to increase cellulose digestibility
314	7.2.2.2.2.3	Develop Zymomonas strain adapted to 100 % hydrolys
315	7.2.2.2.2.4	Complete detoxification process development at the be
316	7.2.2.2.2.5	Provide data on applicability of detoxification to various
317	7.2.2.2.2.6	Investigate SSCF performance by consideration of alte
318	7.2.2.2.2.7	Investigate SSCF performance utilizing improved pretr
319	7.2.2.2.2.8	Improved process technology ready for review and gen
320	7.2.2.2.2.9	Prioritized improvement projects carried out
321	.2.2.2.2.10	Integrated biomass to ethanol technology meeting yeaı

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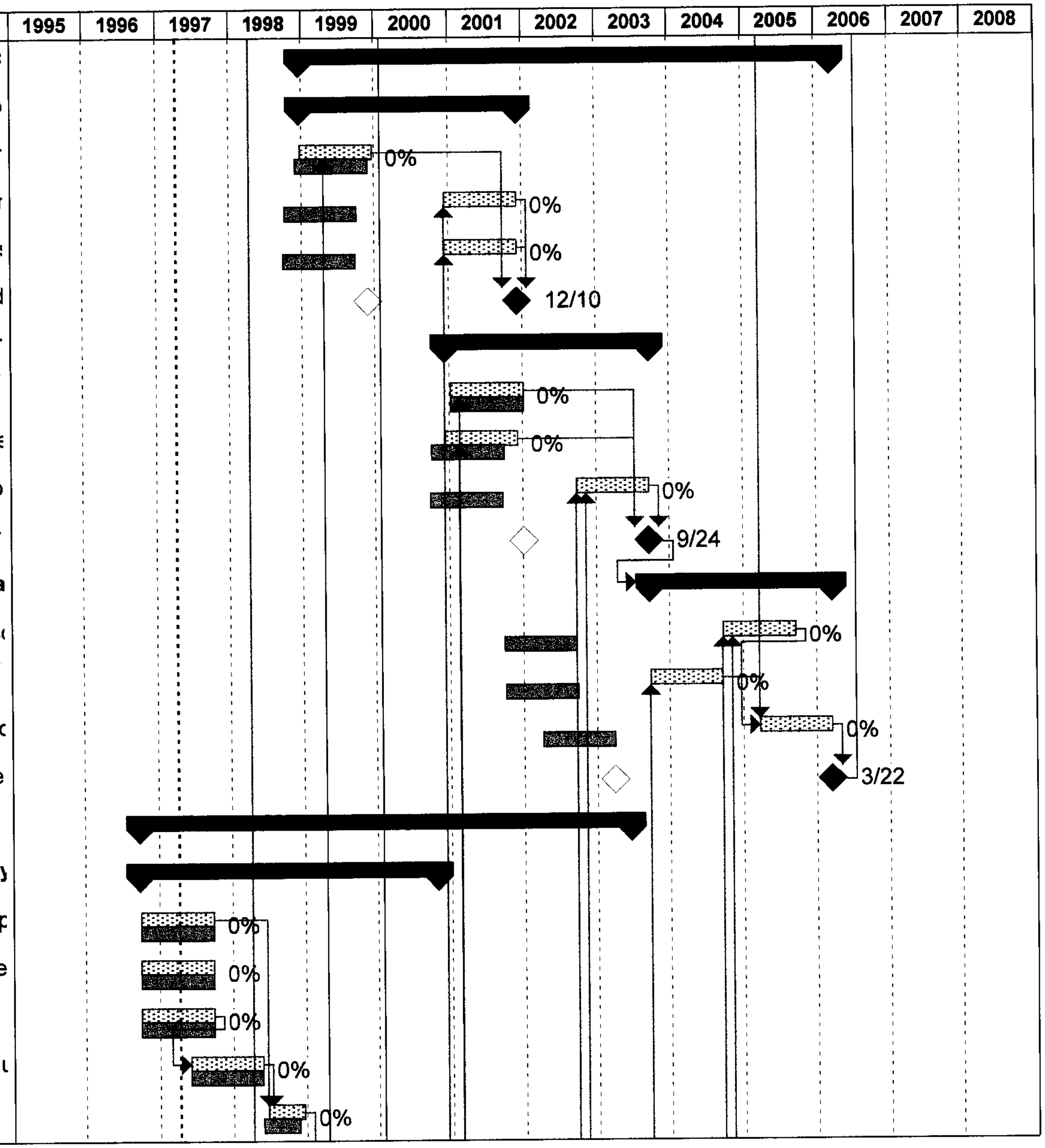
ID	WBS	Task Name
322	**7.2.2.3**	**Test incremental improvements under integrated process c**
323	**7.2.2.3.1**	**First roll-out of improvements in technology for near term v**
324	7.2.2.3.1.1	Test first generation countercurrent prehydrolysis techr
325	7.2.2.3.1.2	Test Phase I genetically engineered cellulase system ir
326	7.2.2.3.1.3	Test improved Zymomonas strain in integrated proces:
327	7.2.2.3.1.4	Documented improvements available for commercial d
328	**7.2.2.3.2**	**Second roll-out of improvements in technology for near ter**
329	7.2.2.3.2.1	Test lignin utilization technology
330	7.2.2.3.2.2	Test second generation countercurrent prehydrolysis te
331	7.2.2.3.2.3	Test "super" Zymomonas strain (robust) and/or Lactob
332	7.2.2.3.2.4	Improved low-value feedstock technology available for
333	**7.2.2.3.3**	**Develop integrated process for switchgrass conversion tha**
334	7.2.2.3.3.1	Test improvements in fermentor strains at the bench sc
335	7.2.2.3.3.2	Test Phase II cellulase system at the bench scale
336	7.2.2.3.3.3	Integrate switchgrass to ethanol process at smallest pc
337	7.2.2.3.3.4	Switchgrass technology available for commercial deve
338	**7.2.3**	**Chemical Hydrolysis R&D**
339	**7.2.3.1**	**Develop countercurrent chemical prehydrolysis technology**
340	7.2.3.1.1	Bench scale development of countercurrent chemical p
341	7.2.3.1.2	Supply test quantities of pretreated feedstocks for othe
342	7.2.3.1.3	Design and procure a prototype reactor
343	7.2.3.1.4	Modify, expand PDU and install and shakedown all equ
344	7.2.3.1.5	Test and modify prototype reactor



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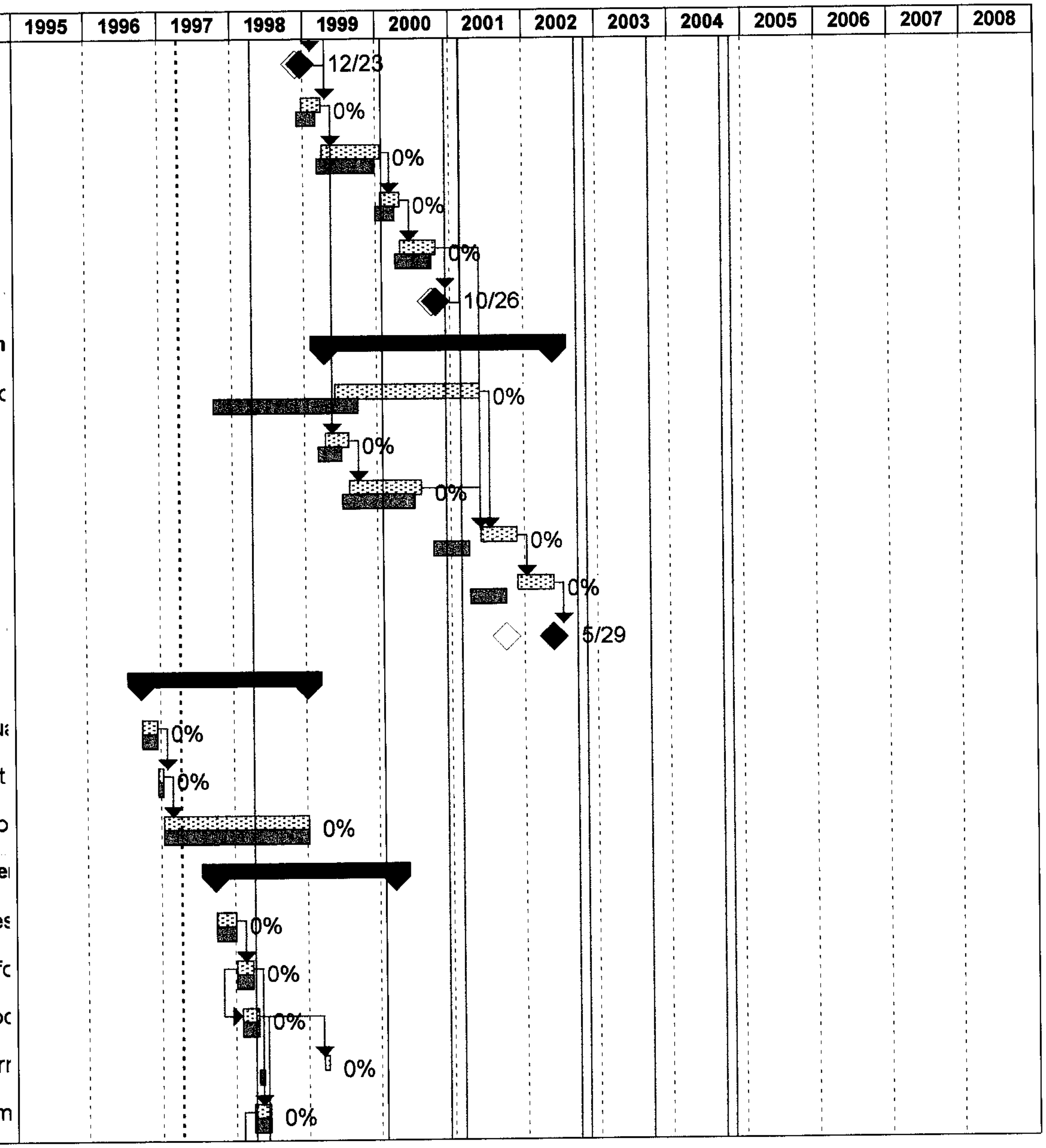
ID	WBS	Task Name
345	7.2.3.1.6	Hand-off prototype to EPD for integrated testing
346	7.2.3.1.7	Design second generation reactor
347	7.2.3.1.8	Procure second generation reactor
348	7.2.3.1.9	Install and shakedown second generation unit
349	7.2.3.1.10	Test and modify second generation unit
350	7.2.3.1.11	Hand-off second generation unit to EPD for integrated
351	**7.2.3.2**	**Develop countercurrent complete chemical hydrolysis tech**
352	7.2.3.2.1	Bench scale development of countercurrent complete c
353	7.2.3.2.2	Design complete hydrolysis reactor
354	7.2.3.2.3	Procure complete hydrolysis reactor
355	7.2.3.2.4	Install and shakedown complete hydrolysis reactor
356	7.2.3.2.5	Initial testing of complete hydrolysis reactor
357	7.2.3.2.6	Hand-off second generation unit to EPD for integrated
358	**7.2.3.3**	**Alternate Pretreatment Evaluation**
359	7.2.3.3.1	Complete Data Analysis and Process Economic Evalu
360	7.2.3.3.2	Develop Strategy for Follow-on Alternate Pretreatment
361	7.2.3.3.3	Further Development/Scale up/Testing of Selected Pro
362	**7.2.3.4**	**Long Term Feedstock (Hardwood) Bench Scale Developme**
363	7.2.3.4.1	Identify and Obtain Representative Hardwood Samples
364	7.2.3.4.2	Determine Countercurrent Prehydrolysis Parameters fc
365	7.2.3.4.3	Determine Best Available Detox Methods for Hardwooc
366	7.2.3.4.4	Quantify Material Balance, Solids Digestibility and Ferr
367	7.2.3.4.5	Determine Countercurrent Complete Hydrolysis Param



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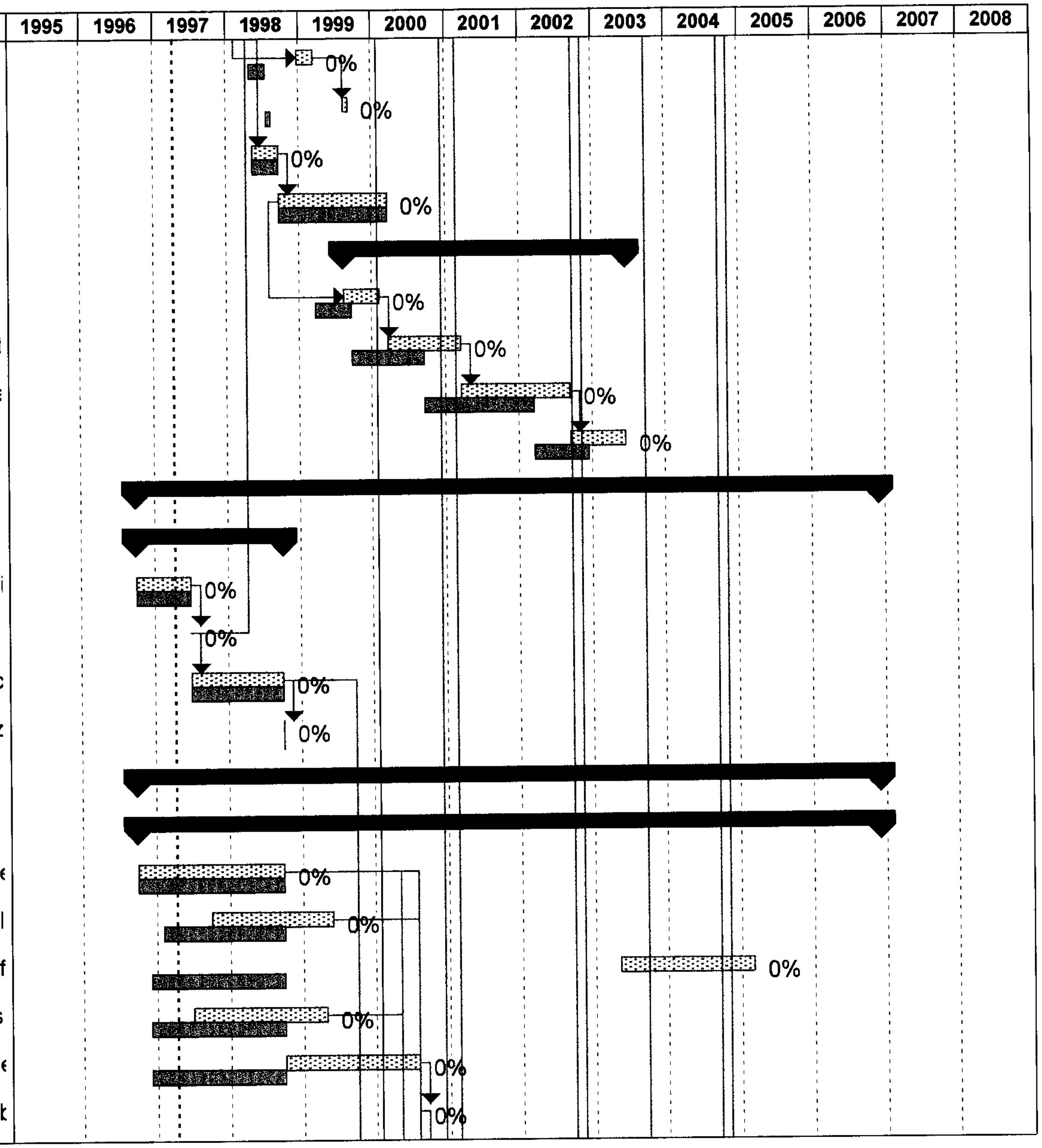
ID	WBS	Task Name
368	7.2.3.4.6	Determine Best Available Detox Methods for Hardwooc
369	7.2.3.4.7	Quantify Material Balance and Fermentability of Std. D
370	7.2.3.4.8	Conduct Preliminary Process Engineering Analysis of I
371	7.2.3.4.9	Scale up Modification/Testing in Appropriate Countercu
372	**7.2.3.5**	**Long Range Advanced Pretreatment Technologies**
373	7.2.3.5.1	Identify Advanced Pretreatment Technologies
374	7.2.3.5.2	Conduct Bench Scale Development Program on Select
375	7.2.3.5.3	Identify and Obtain Appropriate Engineering Scale Rea
376	7.2.3.5.4	Testing of Advanced Pretreatment Technologies at PD
377	**7.2.4**	**Enzyme Technology R&D**
378	**7.2.4.1**	**Near Term Enzyme R&D**
379	7.2.4.1.1	T. reesei: Decrease cellulase cost by optimizing inducti
380	7.2.4.1.2	Deliver new protocols to EPD
381	7.2.4.1.3	T. reesei: Determine effects of induction protocols on c
382	7.2.4.1.4	Report correlation between T. reesei induction and enz
383	**7.2.4.2**	**Mid Term Enzyme R&D**
384	**7.2.4.2.1**	**Develop cost effective enzyme system for pretreated SG**
385	7.2.4.2.1.1	Phase I: Improve action of EI on pSG using site-directe
386	7.2.4.2.1.2	Phase I: Increase Topt and process tolerance of CBH I
387	7.2.4.2.1.3	Perform substrate/cellulose binding domain modeling f
388	7.2.4.2.1.4	Phase I: Increase Topt and process tolerance of E3 us
389	7.2.4.2.1.5	Provide high resolution x-ray structure for E3 and clone
390	7.2.4.2.1.6	Report K Milestone describing cellulase improvement b



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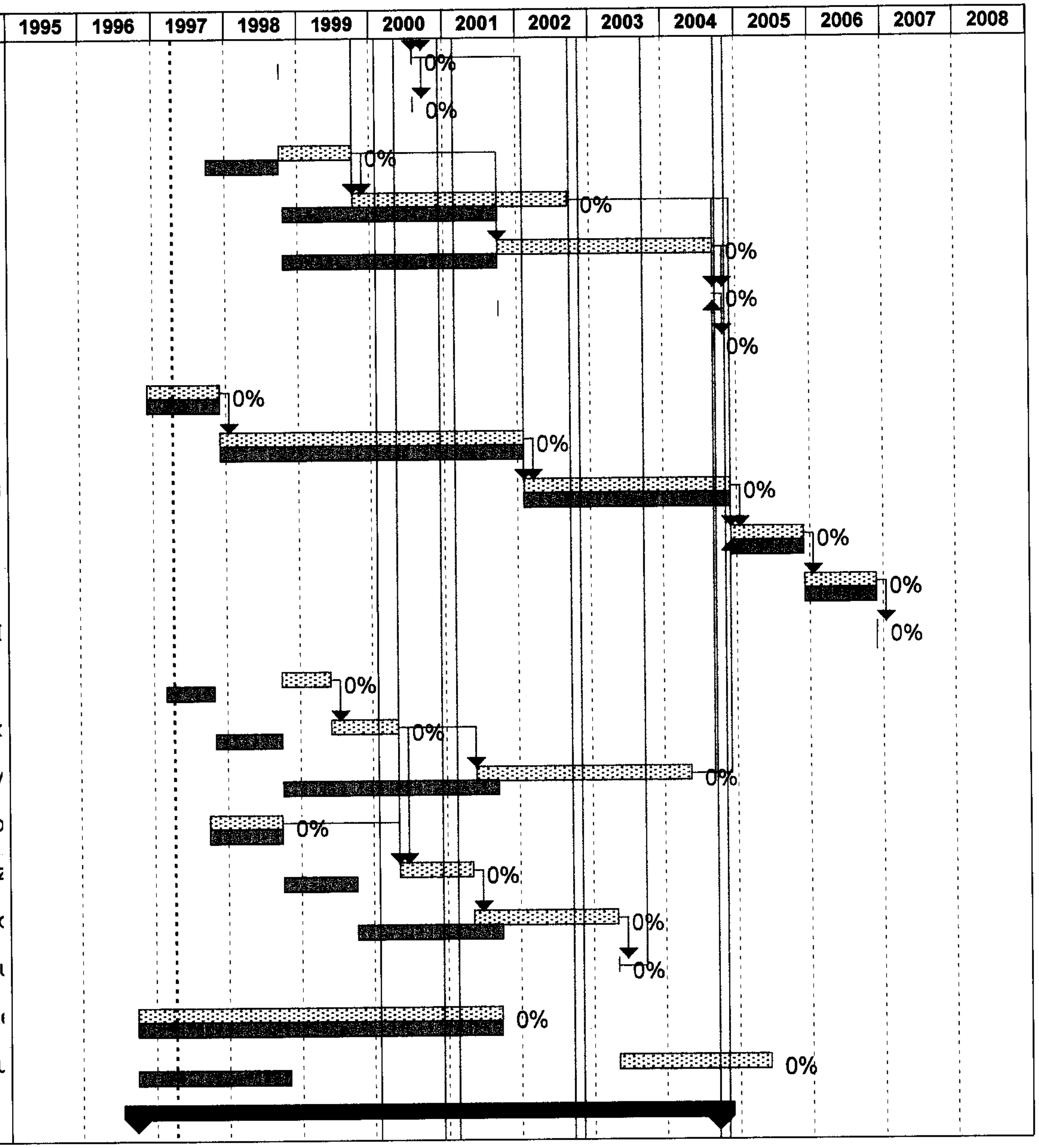
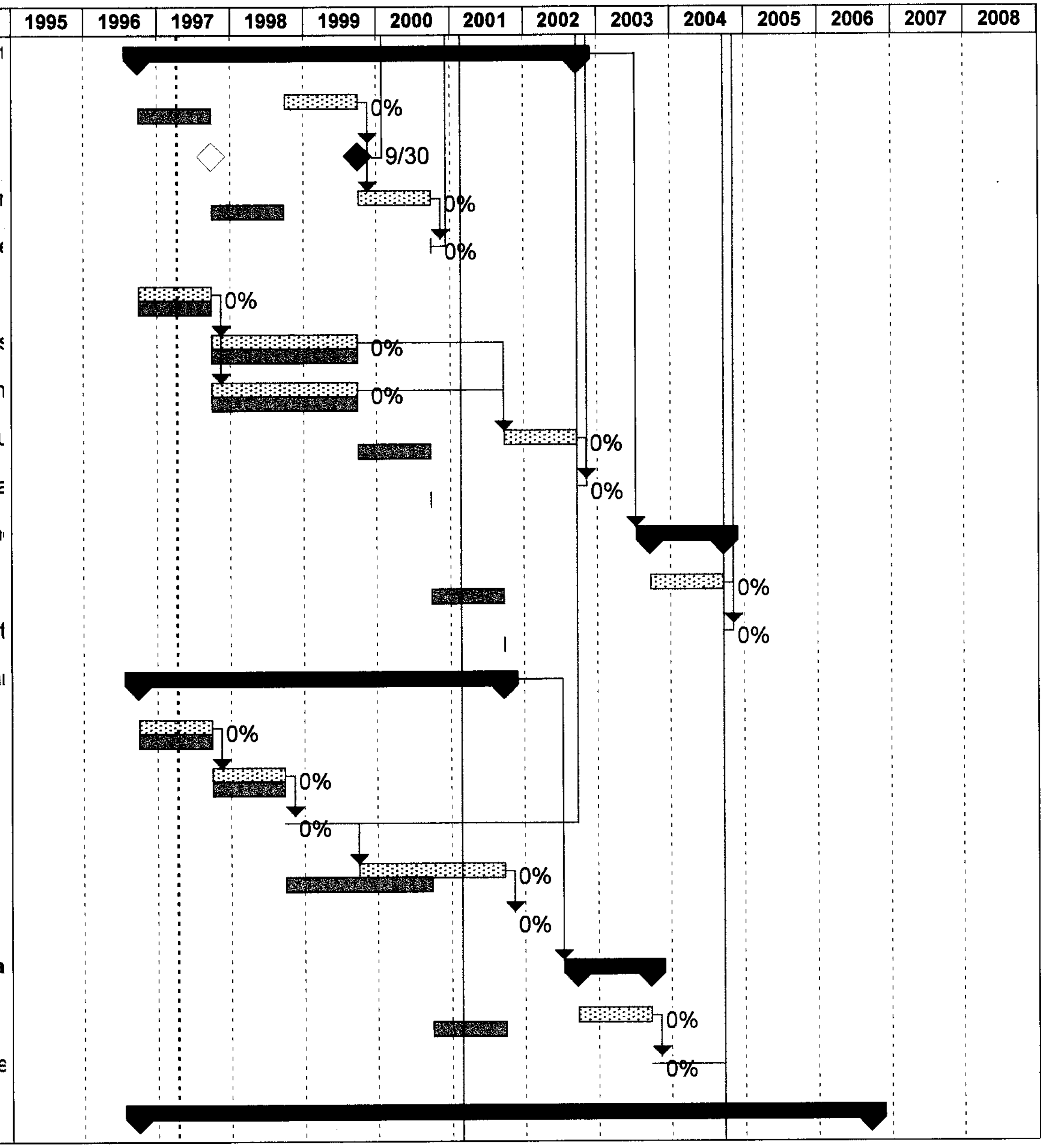
ID	WBS	Task Name
391	7.2.4.2.1.7	Deliver Phase I engineered cellulase system to EPD fo
392	7.2.4.2.1.8	DECISION: Pick plant or submerged culture expressioı
393	7.2.4.2.1.9	Develop strategy to improve active site performance of
394	.2.4.2.1.10	Phase II: Increase specific activity of CBHI on pSG usi
395	.2.4.2.1.11	Phase II: Increase specific activity of E3 on pSG using
396	.2.4.2.1.12	Deliver Phase II engineered cellulase system w access
397	.2.4.2.1.13	DECISION: Pick enzymes or DMC
398	.2.4.2.1.14	Produce rEI, rCBHI, and rE3 in 1st Gen plants
399	.2.4.2.1.15	Evaluate field tests and enzyme recovery schemes
400	.2.4.2.1.16	Produce rEI, rCBHI, and rE3 in 2nd Gen plant systems
401	.2.4.2.1.17	Produce improved rEI, rCBHI, and rE3 in best field cro
402	.2.4.2.1.18	Evaluate field tests and enzyme recovery schemes
403	.2.4.2.1.19	Deliver technology for plant produced cellulases to EPI
404	.2.4.2.1.20	Provide purified accessory enz for testing at NREL
405	.2.4.2.1.21	Determine utility of accessory enz (xylanases, cellodex
406	.2.4.2.1.22	Improve Topt and process tolerance of accessory enzy
407	.2.4.2.1.23	Produce rEI, rCBHI, and E3 in submerged culture (Asp
408	.2.4.2.1.24	Produce Phase I rEI, rCBHI, rE3, and/or accessory enz
409	.2.4.2.1.25	Evaluate Gen II submerged culture production technolc
410	.2.4.2.1.26	Deliver mature technology for submerged culture prodı
411	.2.4.2.1.27	Evaluate new engineered cellulase/accessory enz syst
412	.2.4.2.1.28	Evaluate enzymes expressed from best plant and/or sı
413	**7.2.5**	**Fermentation Organism Development**



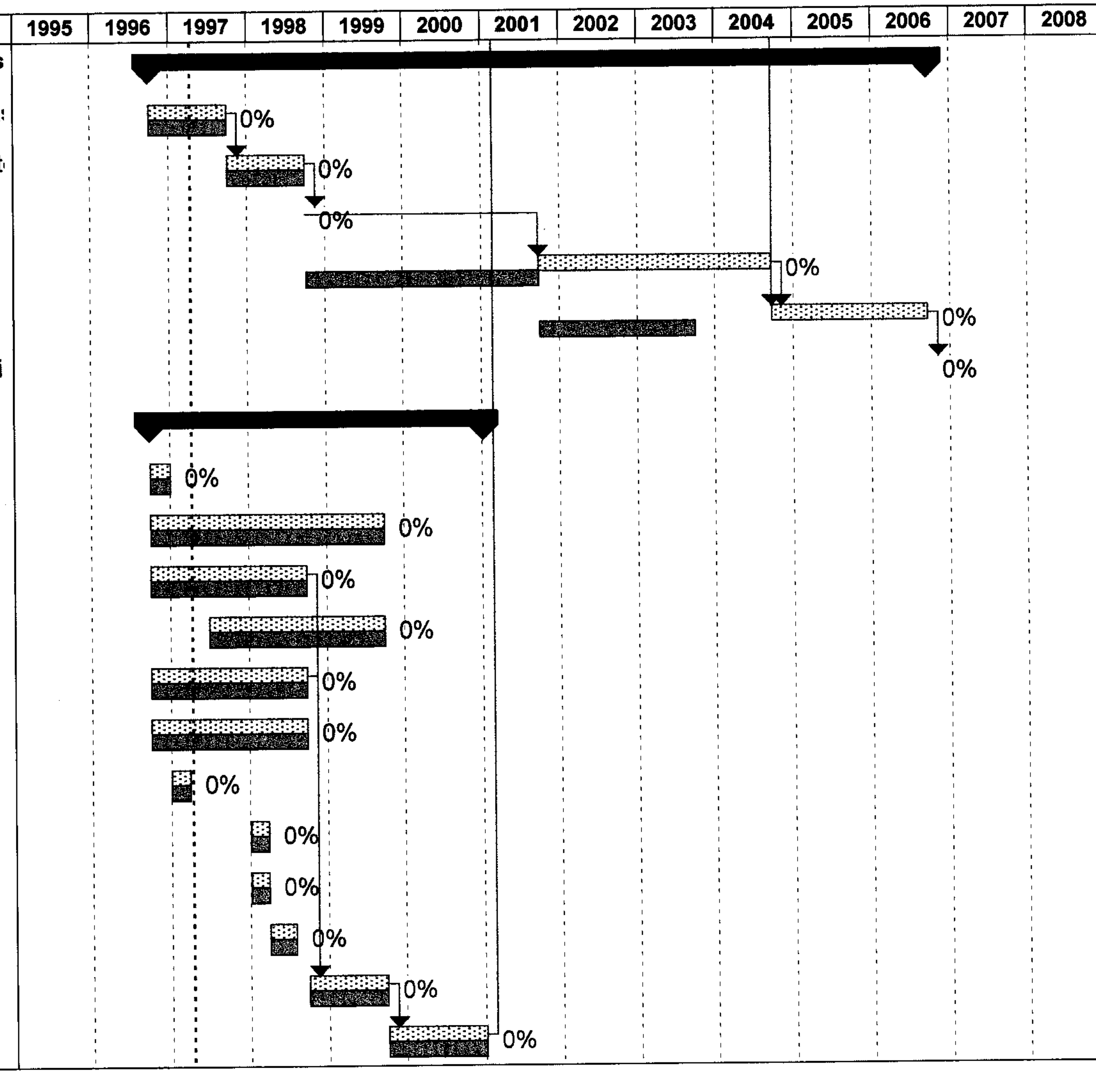
Ethanol Multi-Year Technical Plan
Resource-Leveled Plan Versus Baseline Plan
Bioethanol Program Plan v24 level

ID	WBS	Task Name
414	**7.2.5.1**	**Develop Zymomonas Organism for use in year 2000 waste t**
415	7.2.5.1.1	Evaluate new new Zymomonas strains
416	7.2.5.1.2	Select strains for hand-off to integration studies
417	7.2.5.1.3	Develop further improvements to Zymomonas organisi
418	7.2.5.1.4	Hand-off improved Zymomonas strain for pilot scale de
419	7.2.5.1.5	Investigate new approaches to improving Zymomonas
420	7.2.5.1.6	Begin making metabolic enhancements of Zymomonas
421	7.2.5.1.7	Implement strategies to improve robustness of Zymom
422	7.2.5.1.8	Develop a "super" Zymomonas strain with desired robu
423	7.2.5.1.9	Hand-off advanced Zymomonas strains to industrial pa
424	**7.2.5.2**	**Develop Zymomonas Organism for use in year 2005 switch**
425	7.2.5.2.1	Make adjustments switchgrass
426	7.2.5.2.2	Hand-off switchgrass Zymomonas strain to EPD for int
427	**7.2.5.3**	**Develop a Lactobacillus strain for improved performance ar**
428	7.2.5.3.1	Re-initiate work on lactobacillus
429	7.2.5.3.2	Develop an ethanol producing lactobacillus
430	7.2.5.3.3	Hand-off lactobacillus to EPD for integration and PDU
431	7.2.5.3.4	Assess and improve lactobacillus strains
432	7.2.5.3.5	Hand-off lactobacillus organism to EPD for integration
433	**7.2.5.4**	**Develop Lactobacillus strain for use in year 2005 switchgra**
434	7.2.5.4.1	Make adjustments for switchgrass sugars as needed
435	7.2.5.4.2	Hand-off switchgrass Lactobacillus strain to EPD for te
436	**7.2.6**	**Direct Microbial Conversion Strain Development**



Ethanol Multi-Year Technical Plan
Resource-Leveled Plan Versus Baseline Plan
Bioethanol Program Plan v24 level

ID	WBS	Task Name
437	**7.2.6.1**	**Develop cost effective Zymomonas strains for DMC proces**
438	7.2.6.1.1	Acquire or produce cDNA clone of best beta-glucosida:
439	7.2.6.1.2	Clone cellobiase in best "Z" using best expression vect
440	7.2.6.1.3	Deliver cellobiose fermenting "Z" to EPT for testing
441	7.2.6.1.4	Develop integrated transformation system for Z, using
442	7.2.6.1.5	Clone rEI and rCBHI in best "Z" or Lactobacillus
443	7.2.6.1.6	Deliver engineered "Z" or Lactobacillus to EPT for testi
444	**7.2.7**	**Lignin Utilization R & D**
445	7.2.7.1	Technoeconomic analysis
446	7.2.7.2	Lab optimization of BCD
447	7.2.7.3	Reproducibility and batch scale-up
448	7.2.7.4	Supply lignin to Utah, Sandia and NREL
449	7.2.7.5	Jet reactor BCD process work
450	7.2.7.6	Analysis of BCD products
451	7.2.7.7	Detailed flow diagram: BCD/HPR
452	7.2.7.8	Detailed flow diagram:E+SHR
453	7.2.7.9	Evaluation/ determine product targets
454	7.2.7.10	Technoeconomic analysis of best products
455	7.2.7.11	Scale-up of jet or other reactor
456	7.2.7.12	Pilot plant testing of new reactor



9. The Budget

term goals for the Bioethanol Project. In constant 1996 dollars

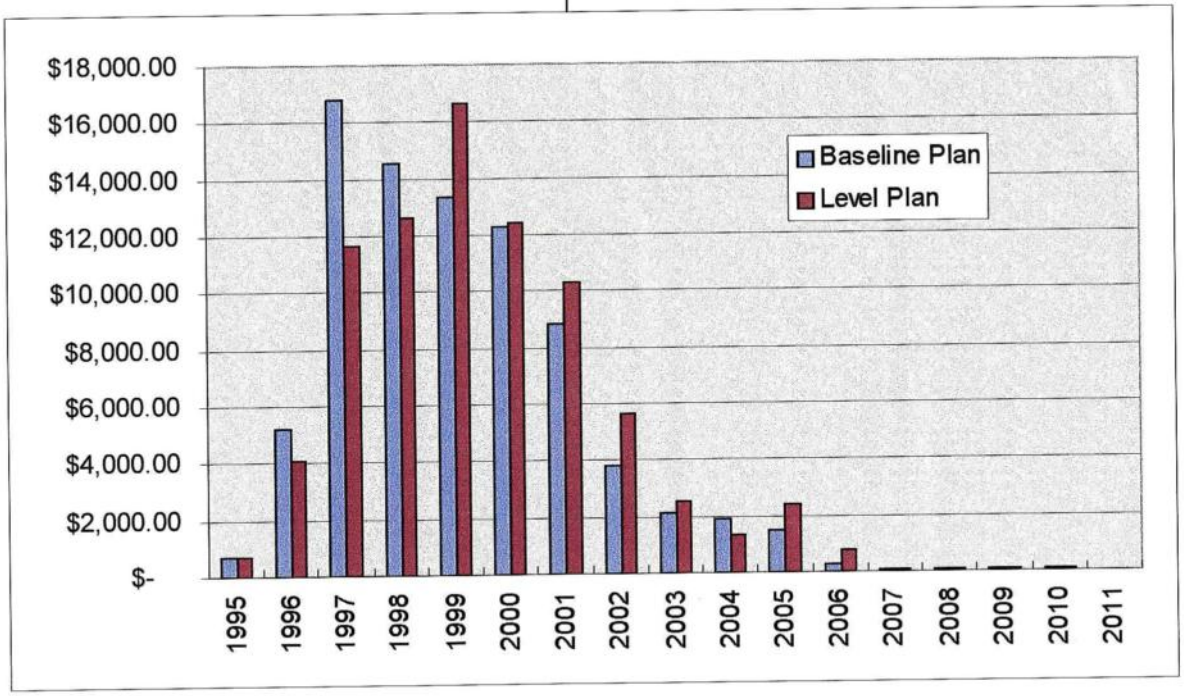


Figure 23 Cost Plan for Meeting the Near and Mid Term Goals for Bioethanol (Costs shown in Thousands of $1996)

The Gantt chart entitled "Ethanol Multi-Year Technical Plan: Bioethanol Program Plan v24" contains budget information for all tasks in the MYTP. For each area of the plan, two types of costs are included: fixed costs and total cost. Fixed costs are associated with subcontracted research and with capital purchases. The difference between total costs and fixed costs is the in-house research work at NREL and ORNL.

9.1 Total Costs

Figure 1 in the Executive Summary shows total costs of around $100 million to meet the near and mid this, this amounts to $83 million dollars (see the first line of the Gantt chart for the baseline program).

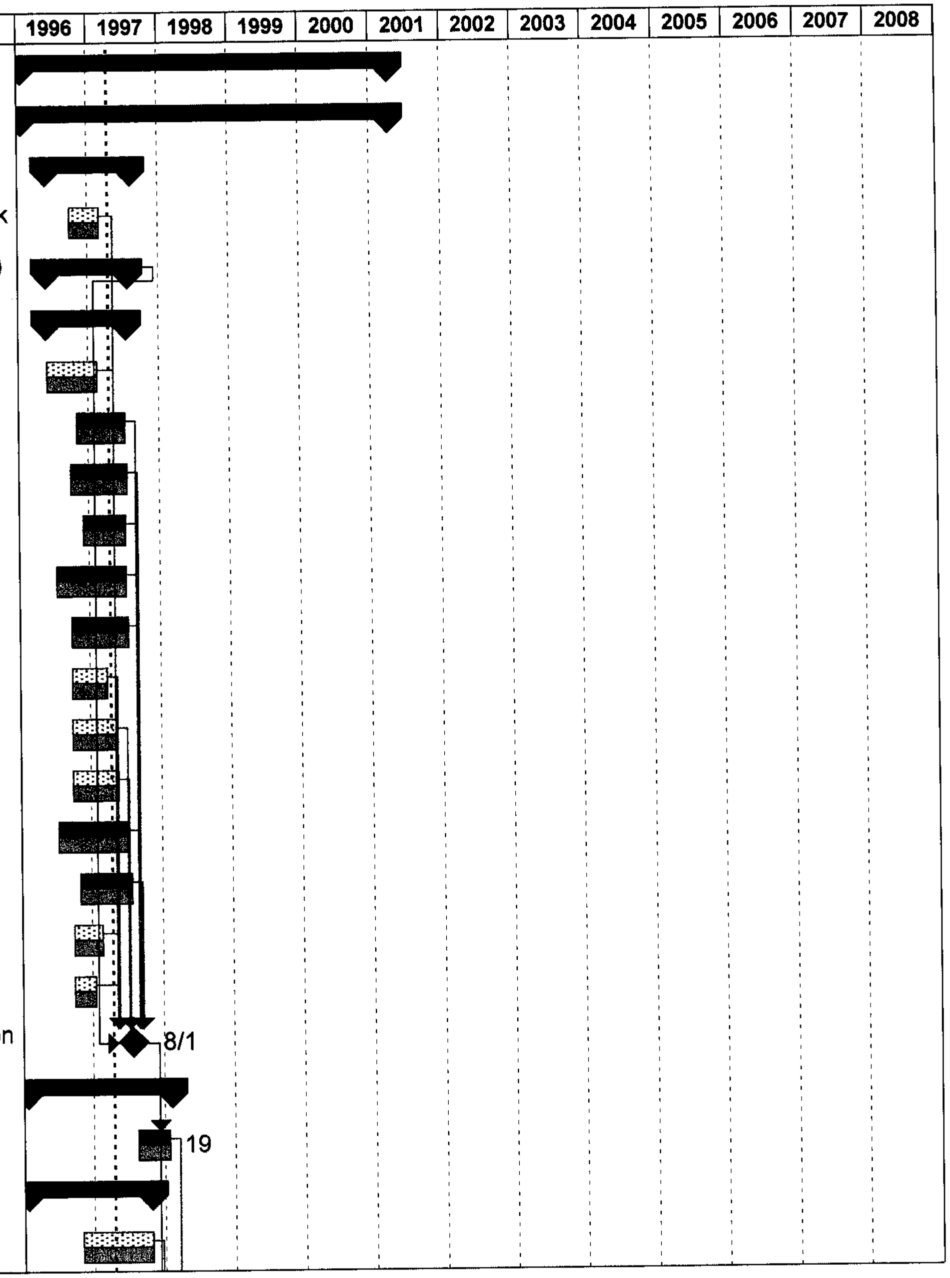
The spending rate for the program differs, of course, for the baseline and the resource leveled version of the plan. Both cost plans are shown in Figure 23. Already it is obvious that there is a problem with the baseline plan, which shows project spending reaching a peak in 1997 and steadily declining after that point. Resource leveling moves this peak out to the year 2000.

9.2 Worksheets

The following pages include worksheets used to determine resource requirements for the plan. The last page of the worksheets shows calculations for the average hourly rate used for all in-house resources (both at NREL and at ORNL).

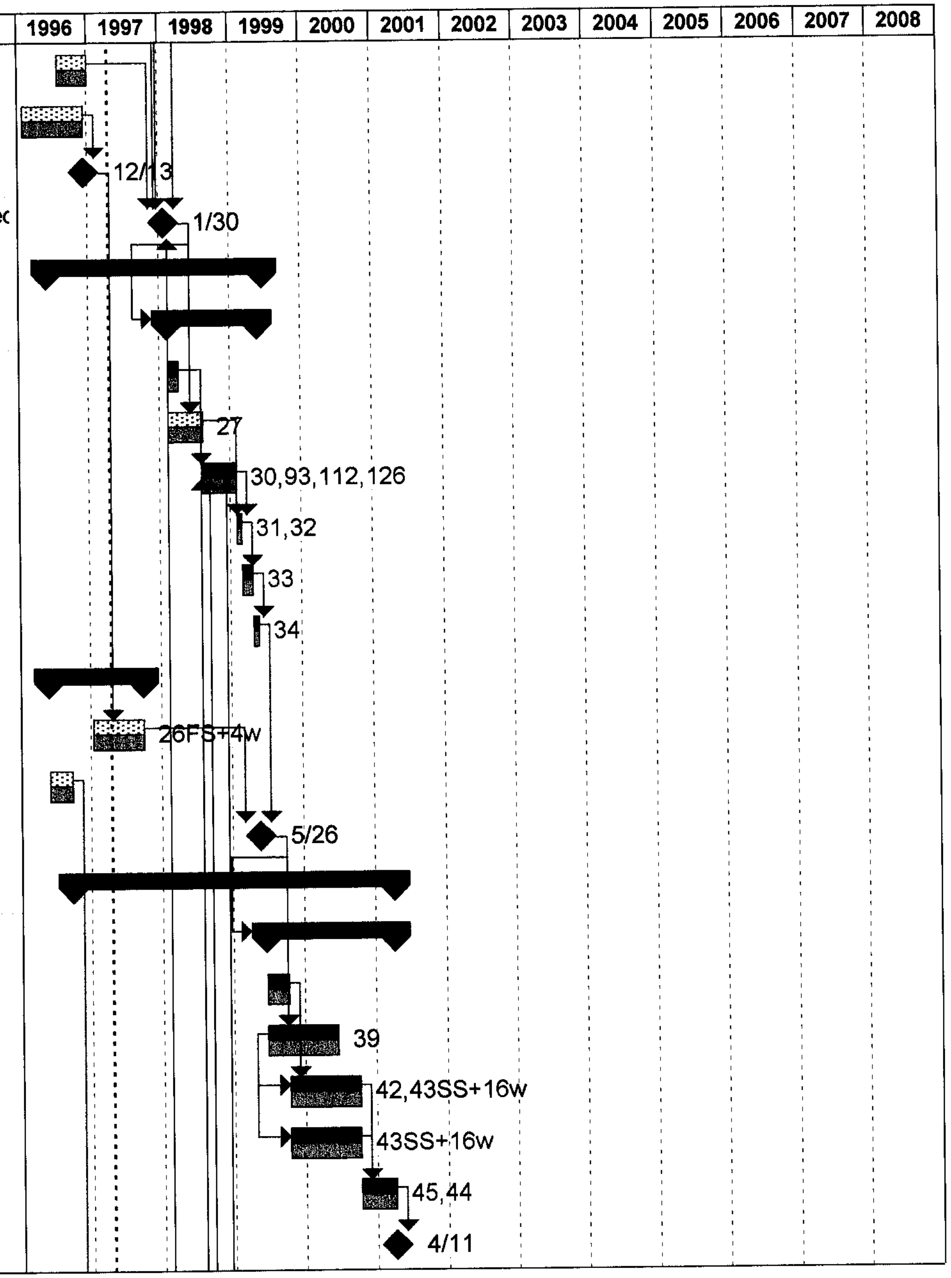
Ethanol Multi-Year Technical Plan
Critical Path Analysis for Near Term Deployment
Bioethanol Program Plan v24 Near Term Critical Path

ID	Task Name
	Bioethanol Program Plan v24 Near Term Critical Path
1	**Commercially demonstrate waste biomass to ethanol technology**
2	**Preliminary Feasibility Studies**
3	Conduct New Preliminary Feasibility Studies (supported by limited laboratory work
4	**Complete Existing Preliminary Feasibility Studies (supported by limited laboratory work)**
5	**Near term softwood opportunities**
6	Quincy Library Group Feasibility Study (softwood)
7	Colorado "Pine Zone" Feasibility Study (softwood)
8	2 contracts (TBD)
9	PALCO and LP Feasibility Studies (softwood)
10	IBI CRADA (softwood)
11	CARB Bioethanol Life Cycle Analysis (softwood)
12	Washington State Energy Office Pulp Mill Feasibility Study (softwood)
13	ACE Feasibility Study (CRP grass)
14	Iowa Feasibility Study (CRP grass)
15	Delta-T CRADA (feedstock to be determined)
16	Cellulase Partnership with Iogen
17	Quaker Oats Chemicals/Manildra Feasibility Study (other feedstock)
18	Pure Vision Feasibility Study (other feedstock)
19	Select Partners for Final Feasibility Studies (apply Final Feasibility Study selection
20	**Final Feasibility Studies**
21	Conduct New Final Feasibility Studies (supported by laboratory work)
22	**Complete Existing Final Feasibility Studies (supported by laboratory work)**
23	Coors CRADA Phase 2 (grain milling residue)



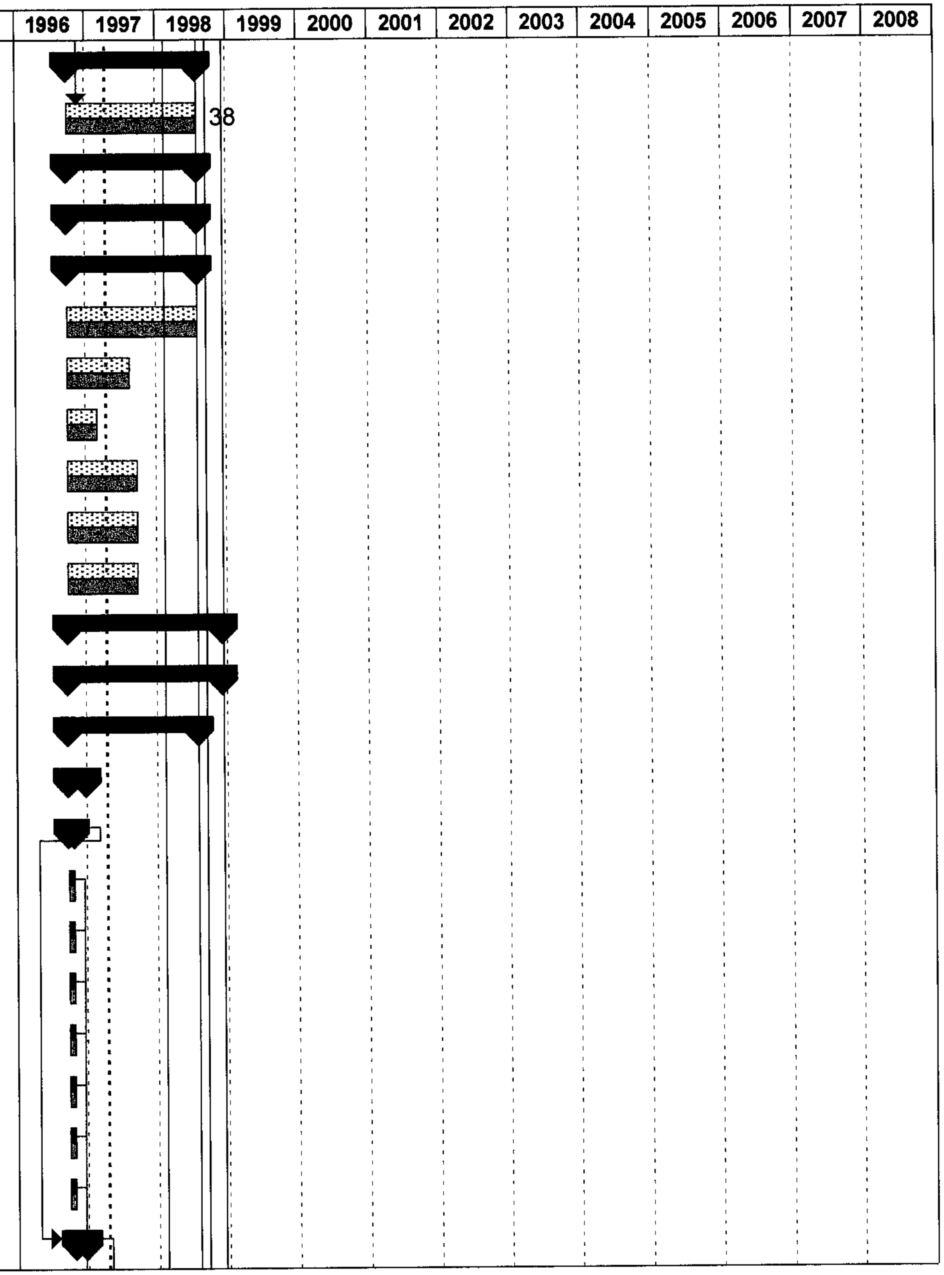
Ethanol Multi-Year Technical Plan
Critical Path Analysis for Near Term Deployment
Bioethanol Program Plan v24 Near Term Critical Path

ID	Task Name
24	New Energy CRADA (grain milling residue)
25	Gridley Project Phase 1 (rice straw)
26	Gridley Phase 2 Go/No-go Decision
27	Select Partners for Business Plan Development (apply demonstration partner selec
28	**Business Plans**
29	**Conduct New Business Plans**
30	Negotiate Legal Arrangements with Partners
31	Establish Feedstock/Product Contracts and Site Commitments
32	Conduct PDU Testing and Data Analysis
33	Re-evaluate Process Design and Cost Estimate
34	Negotiate License Agreements and Performance Guarantees
35	Issue New Business Plans
36	**Complete Existing Business Plans**
37	Gridley Phase 2 - issue business plan
38	Amoco CRADA Phase 3
39	Select Partners for Demonstration Plant Development
40	**Demonstration Plants**
41	**Conduct New Demonstration Plant Efforts**
42	Finance Facility
43	Conduct Detailed Design
44	Obtain Permits
45	Construct Facility
46	Start Up Facility by Year 2000
47	Commercial Operation



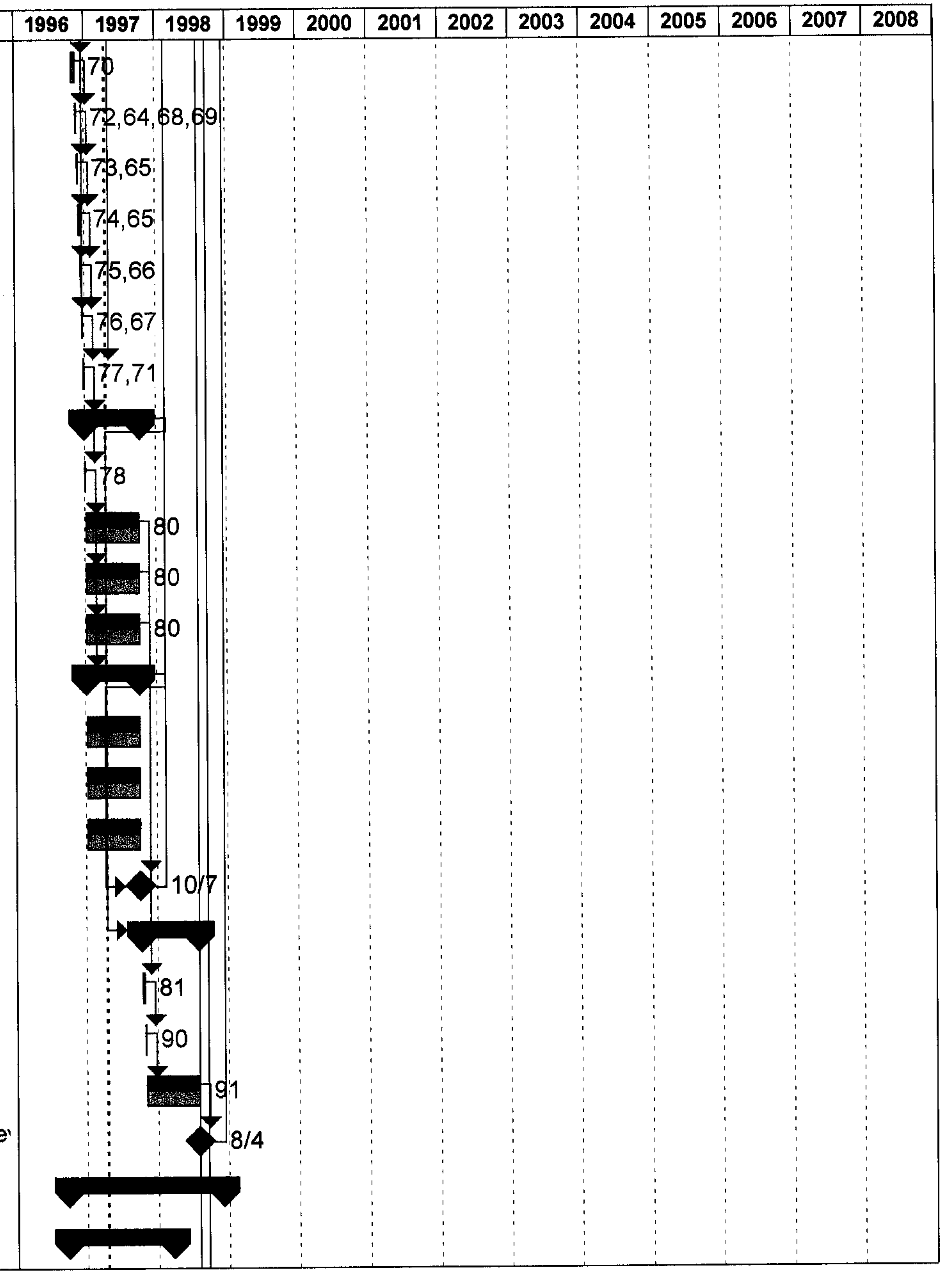
Ethanol Multi-Year Technical Plan
Critical Path Analysis for Near Term Deployment
Bioethanol Program Plan v24 Near Term Critical Path

ID	Task Name
48	**Complete Existing Demonstration Plant Efforts**
49	Amoco CRADA Phase 4 - Final Report on Demonstration Plant Due
50	**Develop and Maintain PDT Capabilities and Data Bases to Support Year 2000 Goal**
51	**PDT Tools, Data Bases and Capabilities to Conduct Feasibility/Business Plans**
52	**Develop Data Base for Near-Term Feedstock**
53	Develop Forest Residue GIS Database
54	Develop Saw & Pulp Mill GIS Database
55	Montana State Wood Waste Assessment
56	Maintain PDT Engineering/Economic Analysis Models
57	Develop Data Base for Sources of Funding to Partners
58	Coordinate With Federal, State, Local & Private Organizations to Support Ethanol
59	**Core Technology Development**
60	**Biomass Conversion Technology**
61	**Softwood-specific process integration and process development activities**
62	**Preliminary Technology Analysis**
63	**Investigate technologies**
64	SO2 steam explosion
65	Dilute acid hydrolysis
66	Concentrated acid
67	ACOS Organosolv process
68	Enzyme production
69	Fermentation/SHF/SSF
70	Lignin utilization
71	**Model 5 process options for softwoods**



Ethanol Multi-Year Technical Plan
Critical Path Analysis for Near Term Deployment
Bioethanol Program Plan v24 Near Term Critical Path

ID	Task Name
72	Complete process & economic model
73	Option A
74	Option B
75	Option C
76	Option D
77	Option E
78	Identify technology gaps
79	**Fill Technology Gaps for Softwoods**
80	Revise softwoods technology plan
81	Subcontract or CRADA with UBC
82	Subcontract #2
83	Subcontract #3
84	**Pretreatment & fermentation work at NREL**
85	Dilute acid pretreatment
86	SO2 Steam explosion
87	C6 Fermentation R&D
88	Preliminary assessment of integrated technologies completed
89	**Process Selection and PDU Testing**
90	Revise Process Models
91	Select Process for further development
92	Subcontract #4
93	Integrated process for softwood to ethanol technology available for commercial de
94	**Process Integration and Process Development**
95	**Provide commercial development facility capabilities to support industrial partners**



Ethanol Multi-Year Technical Plan
Critical Path Analysis for Near Term Deployment
Bioethanol Program Plan v24 Near Term Critical Path

ID	Task Name	1996–2008
96	**Demonstrate an integrated process for ethanol from cellulose in a mini-pilot plant system**	
97	Establish complete integrated process flow diagram for minipilot plant	
98	Prove that aseptic conditions can be maintained in the biochemical conversion unit	97
99	Obtain approval to operate the mini-pilot plant using a genetically engineered micr	98
100	Design, procure and test ion exchange equipment for hydrolysate conditioning	
101	Ready Sunds reactor to produce pretreated sawdust for integrated demonstration	100,99
102	Run process qualifier technology demonstration	101
103	Document process qualifier demonstration	102
104	Mini-pilot biochemical conversion unit available for commercial development	3/18
105	Design full pilot plant scale detoxification equipment	
106	Install full pilot plant scale detoxification equipment	105
107	Test and modify full pilot scale detoxification equipment	106
108	Detoxification process available for pilot scale commercial development	12/23
109	Design SSCF system for pilot plant demonstration based on experimental results a	108
110	Evaluate spent solids for combustion value	108
111	Investigate the impacts of gypsum on the bioethanol process prior to pilot plant tes	108
112	Pilot scale testing capability available for use by commercial partners	3/25
113	**Provide integrated process technology for commercial development meeting the cost tar**	
114	**Develop cellulase enzyme production technology utilizing hydrolysate and pretreated sol**	
115	Establish cellulase production on hydrolysate and pretreated solids	
116	Improve cellulase production on hydrolysate and pretreated solids based on induct	115,132
117	Cellulase enzyme production technology available for commercial development	9/15
118	**Improve integrated process performance to achieve cost target for year 2000 deployment**	
119	Produce pretreated and detoxified materials to meet team experimental needs	

Ethanol Multi-Year Technical Plan
Critical Path Analysis for Near Term Deployment
Bioethanol Program Plan v24 Near Term Critical Path

ID	Task Name	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
120	Improve pretreatment to increase cellulose digestibility and hemicellulose sugar yi													
121	Develop Zymomonas strain adapted to 100 % hydrolysate													
122	Complete detoxification process development at the bench scale													
123	Provide data on applicability of detoxification to various feedstocks			8/5										
124	Investigate SSCF performance by consideration of alternate process configuration		119,121FS-26w,122FS-26w,120,104,96											
125	Investigate SSCF performance utilizing improved pretreatment, best detoxification			120,121,124FF,138										
126	Improved process technology ready for review and generation of new improvemen			5/12										
127	Prioritized improvement projects carried out				126									
128	Integrated biomass to ethanol technology meeting year 2000 performance availabl				12/9									
129	**Enzyme Technology R&D**													
130	**Near Term Enzyme R&D**													
131	T. reesei: Decrease cellulase cost by optimizing induction protocols													
132	Deliver new protocols to EPD		131											
133	T. reesei: Determine effects of induction protocols on component enzymes			132										
134	Report correlation between T. reesei induction and enzyme mix			133										
135	**Fermentation Organism Development**													
136	**Develop Zymomonas Organism for use in year 2000 waste to ethanol facility**													
137	Evaluate new new Zymomonas strains													
138	Select strains for hand-off to integration studies			9/29										
139	Develop further improvements to Zymomonas organism			137										
140	Hand-off improved Zymomonas strain for pilot scale demonstration work with indu			139										

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
187	**Chemical Hydrolysis R&D**	**10/1/96 8:00**	**12/17/02 17:00**	**324.2**	**11.8**	**1382.3**	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 4,876,754**	**$ 650,000**	**$ 3,300,000**	**$ 8,826,754**	
188	**Develop countercurrent chemical prehydrolysis technology**	**10/1/96 8:00**	**10/4/00 17:00**	**209.4**	**11.8**	**431.6**	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 1,522,685**	**$ 150,000**	**$ 2,300,000**	**$ 3,972,685**	
189	Bench scale development of countercurrent chemical prehydrolysis	10/1/96 8:00	9/29/97 17:00	52	2.5	130	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 458,640**	$ 100,000		**$ 558,640**	$100K per year for subcontracts
190	Supply test quantities of pretreated feedstocks for other unit operations	10/1/96 8:00	9/29/97 17:00	52	0.1	5.2	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 18,346**	$ 50,000		**$ 68,346**	$50K per year for subcontracts
191	Design and procure a prototype reactor	10/1/96 8:00	9/29/97 17:00	52	2	104	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 366,912**		$ 800,000	**$ 1,166,912**	
192	Modify, expand PDU and install and shakedown all equipment	6/3/97 8:00	6/1/98 17:00	52	1	52	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 183,456**		$ 300,000	**$ 483,456**	
193	Test and modify prototype reactor	6/2/98 8:00	11/30/98 17:00	26	2	52	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 183,456**		$ 200,000	**$ 383,456**	
194	Hand-off prototype to EPD for integrated testing	12/1/98 8:00	12/1/98 17:00	0		0	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ -**			**$ -**	
195	Design second generation reactor	12/2/98 8:00	3/9/99 17:00	14	1	14	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 49,392**			**$ 49,392**	
196	Procure second generation reactor	3/10/99 8:00	12/28/99 17:00	42	0.2	8.4	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 29,635**		$ 800,000	**$ 829,635**	
197	Install and shakedown second generation unit	12/29/99 8:00	4/4/00 17:00	14	1	14	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 49,392**		$ 100,000	**$ 149,392**	
198	Test and modify second generation unit	4/5/00 8:00	10/3/00 17:00	26	2	52	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 183,456**		$ 100,000	**$ 283,456**	
199	Hand-off second generation unit to EPD for integrated testing	10/4/00 8:00	10/4/00 17:00	0		0	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ -**			**$ -**	
200	**Develop countercurrent complete chemical hydrolysis technology**	**9/30/97 8:00**	**10/3/01 17:00**	**209.4**		**365.4**	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 1,289,131**	**$ 300,000**	**$ 700,000**	**$ 2,289,131**	
201	Bench scale development of countercurrent complete chemical hydrolysis	9/30/97 8:00	9/27/99 17:00	104	2.5	260	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 917,280**	$ 300,000		**$ 1,217,280**	$150K per year for subcontracts
202	Design complete hydrolysis reactor	3/10/99 8:00	7/6/99 17:00	17	1	17	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 59,976**			**$ 59,976**	
203	Procure complete hydrolysis reactor	7/7/99 8:00	7/4/00 17:00	52	0.2	10.4	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 36,691**		$ 500,000	**$ 536,691**	
204	Install and shakedown complete hydrolysis reactor	10/4/00 8:00	4/3/01 17:00	26	1	26	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 91,728**		$ 100,000	**$ 191,728**	
205	Initial testing of complete hydrolysis reactor	4/4/01 8:00	10/2/01 17:00	26	2	52	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 183,456**		$ 100,000	**$ 283,456**	
206	Hand-off second generation unit to EPD for integrated testing	10/3/01 8:00	10/3/01 17:00	0		0	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ -**			**$ -**	
207	**Alternate Pretreatment Evaluation**	**10/1/96 8:00**	**1/11/99 17:00**	**119**		**33.8**	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 119,246**	**$ -**	**$ -**	**$ 119,246**	
208	Complete Data Analysis and Process Economic Evaluation of Alternate Pretreatments	10/1/96 8:00	12/16/96 17:00	11	1	11	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 38,808**			**$ 38,808**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
209	Develop Strategy for Follow-on Alternate Pretreatment Work	12/17/96 8:00	1/13/97 17:00	4	0.5	2	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 7,056**			**$ 7,056**	
210	Further Development/Scale up/Testing of Selected Promising Alternate Pretreatment(s)	1/14/97 8:00	1/11/99 17:00	104	0.2	20.8	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 73,382**			**$ 73,382**	
211	**Long Term Feedstock (Hardwood) Bench Scale Development**	**10/1/97 8:00**	**3/21/00 17:00**	**129**		**291.5**	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 1,028,412**	**$ -**	**$ 200,000**	**$ 1,228,412**	
212	Identify and Obtain Representative Hardwood Samples	10/1/97 8:00	1/6/98 17:00	14	0.5	7	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 24,696**			**$ 24,696**	
213	Determine Countercurrent Prehydrolysis Parameters for Hardwood	1/7/98 8:00	3/31/98 17:00	12	2	24	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 84,672**			**$ 84,672**	
214	Determine Best Available Detox Methods for Hardwood Prehydrolyzates	2/4/98 8:00	4/28/98 17:00	12	1.5	18	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 63,504**			**$ 63,504**	
215	Quantify Material Balance, Solids Digestibility and Fermentability of Std. Detox. Prehydrolyzate	4/29/98 8:00	5/26/98 17:00	4	2	8	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 28,224**			**$ 28,224**	
216	Determine Countercurrent Complete Hydrolysis Parameters for Hardwood	4/1/98 8:00	6/23/98 17:00	12	2	24	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 84,672**			**$ 84,672**	
217	Determine Best Available Detox Methods for Hardwood Complete Hydrolyzates	4/29/98 8:00	7/21/98 17:00	12	1.5	18	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 63,504**			**$ 63,504**	
218	Quantify Material Balance and Fermentability of Std. Detox. Hydrolyzate	7/22/98 8:00	8/18/98 17:00	4	2	8	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 28,224**			**$ 28,224**	
219	Conduct Preliminary Process Engineering Analysis of Hardwood Countercurrent Pretreatment	5/13/98 8:00	9/22/98 17:00	19	1.5	28.5	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 100,548**			**$ 100,548**	
220	Scale up Modification/Testing in Appropriate Countercurrent PDU Reactor	9/23/98 8:00	3/21/00 17:00	78	2	156	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 550,368**		$ 200,000	**$ 750,368**	
221	**Long Range Advanced Pretreatment Technologies**	**3/24/99 8:00**	**12/17/02 17:00**	**195**		**260**	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 917,280**	**$ 200,000**	**$ 100,000**	**$ 1,217,280**	
222	Identify Advanced Pretreatment Technologies	3/24/99 8:00	9/21/99 17:00	26	0.5	13	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 45,864**			**$ 45,864**	
223	Conduct Bench Scale Development Program on Selected Advanced Pretreatment Technologies	9/22/99 8:00	9/19/00 17:00	52	2.5	130	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 458,640**	$ 200,000		**$ 658,640**	$200K per year in subcontracts
224	Identify and Obtain Appropriate Engineering Scale Reactor for Advanced Pretreatment Technology	9/20/00 8:00	3/19/02 17:00	78	0.5	39	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 137,592**		$ 100,000	**$ 237,592**	
225	Testing of Advanced Pretreatment Technologies at PDU Scale	3/20/02 8:00	12/17/02 17:00	39	2	78	**Chem Hydrolysis**	**HYD**	**$ 183,456**	**$ 275,184**			**$ 275,184**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
1	**Commercially demonstrate waste biomass to ethanol technology**	**2/1/96 8:00**	**4/5/01 17:00**	**270.2**		**614.43**	**Comm Develop**	**COM**	**$ 183,456**	**$ 2,167,709**	**$ 5,119,113.00**	**$ 2,000,000.00**	**$9,286,822**	
2	**Preliminary Feasibility Studies**	**6/3/96 8:00**	**8/14/97 17:00**	**62.8**		**194.68**	**Comm Develop**	**COM**	**$ 183,456**	**$ 686,831**	**$ 870,000.00**	**$ -**	**$1,556,831**	
3	Conduct New Preliminary Feasibility Studies (supported by limited laboratory work)	10/1/96 8:00	3/3/97 17:00	22	3.55	78	**Comm Develop**	**COM**	**$ 183,456**	**$ 275,184**	$ 300,000.00		**$ 575,184**	Assumes three preliminary studies underway requiring .5 fte each and $100K each in subcontracts
4	**Complete Existing Preliminary Feasibility Studies (supported by limited laboratory work)**	**6/3/96 8:00**	**7/31/97 17:00**	**60.8**		**108.88**	**Comm Develop**	**COM**	**$ 183,456**	**$ 384,129**	**$ 570,000.00**	**$ -**	**$ 954,129**	
5	**Near term softwood opportunities**	**6/3/96 8:00**	**7/21/97 17:00**	**59.2**		**71.96**	**Comm Develop**	**COM**	**$ 183,456**	**$ 253,875**	**$ 350,000.00**	**$ -**	**$ 603,875**	
6	Quincy Library Group Feasibility Study (softwood)	6/3/96 8:00	2/17/97 17:00	37.2	0.21	7.8	**Comm Develop**	**COM**	**$ 183,456**	**$ 27,518**	$ 225,000.00		**$ 252,518**	Labor based on 0.15 ftes of work (PDT Plan 7/96). Two subcontracts for feasibility and project development
7	Colorado "Pine Zone" Feasibility Study (softwood)	11/1/96 8:00	7/10/97 17:00	36	0.33	11.96	**Comm Develop**	**COM**	**$ 183,456**	**$ 42,195**			**$ 42,195**	0.23 ftes (PDT Plan 7/96). No subcontract
8	Colorado Front Range Feasibility Study (softwood)	10/1/96 8:00	7/21/97 17:00	42	0.35	14.56	**Comm Develop**	**COM**	**$ 183,456**	**$ 51,368**	$ 35,000.00		**$ 86,368**	0.28 ftes (PDT Plan 7/96)
9	PALCO and LP Feasibility Studies (softwood)	12/2/96 8:00	7/11/97 17:00	32	0.13	4.16	**Comm Develop**	**COM**	**$ 183,456**	**$ 14,676**			**$ 14,676**	0.08 ftes (PDT Plan 7/96)
10	IBI CRADA (softwood)	7/15/96 8:00	7/11/97 17:00	52	0.24	12.48	**Comm Develop**	**COM**	**$ 183,456**	**$ 44,029**			**$ 44,029**	0.24 ftes (PDT Plan 7/96)
11	CARB Bioethanol Life Cycle Analysis (softwood)	10/1/96 8:00	7/21/97 17:00	42	0.5	21	**Comm Develop**	**COM**	**$ 183,456**	**$ 74,088**	$ 90,000.00		**$ 164,088**	
12	Washington State Energy Office Pulp Mill Feasibility Study (softwood)	10/1/96 8:00	3/31/97 17:00	26	0.08	2.08	**Comm Develop**	**COM**	**$ 183,456**	**$ 7,338**			**$ 7,338**	
13	ACE Feasibility Study (CRP grass)	10/1/96 8:00	5/19/97 17:00	33	0.09	3.12	**Comm Develop**	**COM**	**$ 183,456**	**$ 11,007**	$ 120,000.00		**$ 131,007**	0.06 ftes of work (PDT Plan 7/96)
14	Iowa Feasibility Study (CRP grass)	10/1/96 8:00	5/26/97 17:00	34	0.46	15.6	**Comm Develop**	**COM**	**$ 183,456**	**$ 55,037**			**$ 55,037**	0.3 ftes of work (PDT Plan 7/96)
15	Delta-T CRADA (feedstock to be determined)	7/15/96 8:00	7/11/97 17:00	52	0.25	13	**Comm Develop**	**COM**	**$ 183,456**	**$ 45,864**			**$ 45,864**	FY 97 AOP
16	Cellulase Partnership with logen	11/1/96 8:00	7/31/97 17:00	39		0	**Comm Develop**	**COM**	**$ 183,456**	**$ -**	$ 100,000.00		**$ 100,000**	
17	Quaker Oats Chemicals/Manildra Feasibility Study (other feedstock)	10/1/96 8:00	2/24/97 17:00	21	0.12	2.6	**Comm Develop**	**COM**	**$ 183,456**	**$ 9,173**			**$ 9,173**	0.05 ftes of work (PDT Plan 7/96)
18	Pure Vision Feasibility Study (other feedstock)	10/1/96 8:00	1/20/97 17:00	16	0.16	2.6	**Comm Develop**	**COM**	**$ 183,456**	**$ 9,173**			**$ 9,173**	0.05 ftes of work (PDT Plan 7/96)
19	Select Partners for Final Feasibility Studies (apply Final Feasibility Study selection criteria)	8/1/97 8:00	8/14/97 17:00	2	3.9	7.8	**Comm Develop**	**COM**	**$ 183,456**	**$ 27,518**			**$ 27,518**	Assume 0.15 many years of work

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
20	**Final Feasibility Studies**	**2/1/96 8:00**	**2/12/98 17:00**	**106.2**		**7.8**	**Comm Develop**	**COM**	**$ 183,456**	**$ 27,518**	**$ 2,463,157.00**	**$ -**	**$2,490,675**	
21	Conduct New Final Feasibility Studies (supported by laboratory work)	8/15/97 8:00	1/29/98 17:00	24	9.6	230.36	**Comm Develop**	**COM**	**$ 183,456**	**$ 812,710**	$ 2,463,157.00		**$3,275,867**	Estimated as the cost of Gridley phases 1 and 2. Split in house labor as 0.5 ftes for PDT and 9.1 ftes for pilot plant
22	**Complete Existing Final Feasibility Studies (supported by laboratory work)**	**2/1/96 8:00**	**10/30/97 17:00**	**91.2**		**157.04**	**Comm Develop**	**COM**	**$ 183,456**	**$ 554,037**	**$ 997,201.00**	**$ -**	**$1,551,238**	
23	Coors CRADA Phase 2 (grain milling residue)	11/1/96 8:00	10/30/97 17:00	52	1.3	67.6	**Comm Develop**	**COM**	**$ 183,456**	**$ 238,493**			**$ 238,493**	
24	New Energy CRADA (grain milling residue)	8/1/96 8:00	1/1/97 17:00	22	0.78	17.16	**Comm Develop**	**COM**	**$ 183,456**	**$ 60,540**			**$ 60,540**	0.33 ftes of work (97 AOP)
25	Gridley Project Phase 1 (rice straw)	2/1/96 8:00	12/13/96 12:00	45.3	1.6	72.28	**Comm Develop**	**COM**	**$ 183,456**	**$ 255,004**	$ 997,201.00		**$1,252,205**	Phase I subcontract to SWAN. 20% of the total cost to be borne by subcontractor.In-house cost from WP 3201, 3203, 3300 in FY 97 AOP. Also includes a full fte of effort from 96.
26	Gridley Phase 2 Go/No-go Decision	12/13/96 13:00	12/13/96 17:00	0.5		0	**Comm Develop**	**COM**	**$ 183,456**	**$ -**			**$ -**	
27	Select Partners for Business Plan Development (apply demonstration partner selection criteria)	1/30/98 8:00	2/12/98 17:00	2	3.9	7.8	**Comm Develop**	**COM**	**$ 183,456**	**$ 27,518**			**$ 27,518**	
28	**Business Plans**	**6/3/96 8:00**	**6/16/99 17:00**	**158.6**		**376.96**	**Comm Develop**	**COM**	**$ 183,456**	**$ 1,329,915**	**$ 1,665,956.00**	**$ -**	**$2,995,871**	
29	**Conduct New Business Plans**	**2/13/98 8:00**	**5/19/99 17:00**	**65.8**		**211.08**	**Comm Develop**	**COM**	**$ 183,456**	**$ 744,690**	**$ 200,000.00**	**$ -**	**$ 944,690**	
30	Negotiate Legal Arrangements with Partners	2/13/98 8:00	4/9/98 17:00	8	2	16	**Comm Develop**	**COM**	**$ 183,456**	**$ 56,448**			**$ 56,448**	
31	Establish Feedstock/Product Contracts and Site Commitments	2/13/98 8:00	8/13/98 17:00	26	0.5	13	**Comm Develop**	**COM**	**$ 183,456**	**$ 45,864**			**$ 45,864**	
32	Conduct PDU Testing and Data Analysis	7/30/98 8:00	1/27/99 17:00	26	6.08	158.08	**Comm Develop**	**COM**	**$ 183,456**	**$ 557,706**	$ 200,000.00		**$ 757,706**	Labor from 3.04 ftes in 97 AOP for WP 3300, 3302, 3303. Added $200K in ODCs for pilot plant
33	Re-evaluate Process Design and Cost Estimate	1/28/99 8:00	2/24/99 17:00	4	1	4	**Comm Develop**	**COM**	**$ 183,456**	**$ 14,112**			**$ 14,112**	
34	Negotiate License Agreements and Performance Guarantees	2/25/99 8:00	4/21/99 17:00	8	2	16	**Comm Develop**	**COM**	**$ 183,456**	**$ 56,448**			**$ 56,448**	
35	Issue New Business Plans	4/22/99 8:00	5/19/99 17:00	4	1	4	**Comm Develop**	**COM**	**$ 183,456**	**$ 14,112**			**$ 14,112**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
36	**Complete Existing Business Plans**	**6/3/96 8:00**	**10/3/97 17:00**	**70**		**158.08**	**Comm Develop**	**COM**	**$ 183,456**	**$ 557,706**	**$ 1,465,956.00**	**$ -**	**$2,023,662**	
37	Gridley Phase 2 - issue business plan	1/13/97 8:00	10/3/97 17:00	38	4.16	158.08	**Comm Develop**	**COM**	**$ 183,456**	**$ 557,706**	$ 1,465,956.00		**$2,023,662**	Under subcontracts,$200,000 is included for materials costs to operate PDU
38	Amoco CRADA Phase 3	6/3/96 8:00	9/30/96 17:00	17.2		0	**Comm Develop**	**COM**	**$ 183,456**	**$ -**			**$ -**	
39	Select Partners for Demonstration Plant Development	5/20/99 8:00	6/16/99 17:00	4	3.9	15.6	**Comm Develop**	**COM**	**$ 183,456**	**$ 27,518**			**$ 27,518**	Because demonstration plant selection is assumed to be more complex, work is double that of previous selection efforts
40	**Demonstration Plants**	**10/1/96 8:00**	**4/5/01 17:00**	**235.6**		**34.99**	**Comm Develop**	**COM**	**$ 183,456**	**$ 123,445**	**$ 120,000.00**	**$ 2,000,000.00**	**$2,243,445**	
41	**Conduct New Demonstration Plant Efforts**	**6/17/99 8:00**	**4/5/01 17:00**	**94.2**		**30.2**	**Comm Develop**	**COM**	**$ 183,456**	**$ 106,546**	**$ 120,000.00**	**$ 2,000,000.00**	**$2,226,546**	
42	Finance Facility	6/17/99 8:00	10/6/99 17:00	16	0.1	1.6	**Comm Develop**	**COM**	**$ 183,456**	**$ 5,645**			**$ 5,645**	
43	Conduct Detailed Design	6/17/99 8:00	6/14/00 17:00	52	0.1	5.2	**Comm Develop**	**COM**	**$ 183,456**	**$ 18,346**	$ 100,000.00		**$ 118,346**	Only 10% of the cost is assumed to be carried by DOE.
44	Obtain Permits	10/7/99 8:00	10/4/00 17:00	52	0.1	5.2	**Comm Develop**	**COM**	**$ 183,456**	**$ 18,346**	$ 20,000.00		**$ 38,346**	Only 10% of the cost is assumed to be carried by DOE.
45	Construct Facility	10/7/99 8:00	10/4/00 17:00	52	0.1	5.2	**Comm Develop**	**COM**	**$ 183,456**	**$ 18,346**		$ 2,000,000.00	**$2,018,346**	Only 10% of the cost is assumed to be carried by DOE.
46	Start Up Facility by Year 2000	10/5/00 8:00	4/4/01 17:00	26	0.5	13	**Comm Develop**	**COM**	**$ 183,456**	**$ 45,864**			**$ 45,864**	Only 10% of the cost is assumed to be carried by DOE.
47	Commercial Operation	4/5/01 8:00	4/5/01 17:00	0		0	**Comm Develop**	**COM**	**$ 183,456**	**$ -**			**$ -**	
48	**Complete Existing Demonstration Plant Efforts**	**10/1/96 8:00**	**7/31/98 17:00**	**95.8**		**4.79**	**Comm Develop**	**COM**	**$ 183,456**	**$ 16,899**	**$ -**	**$ -**	**$ 16,899**	
49	Amoco CRADA Phase 4 - Final Report on Demonstration Plant Due	10/1/96 8:00	7/31/98 17:00	95.8	0.05	4.79	**Comm Develop**	**COM**	**$ 183,456**	**$ 16,899**			**$ 16,899**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
63	**Commercially demonstrate switchgrass to ethanol technology**	**5/20/99 8:00**	**12/9/05 17:00**	**342.4**		**478.56**	**Comm Develop**	**COM**	**$183,456**	**$ 1,688,360**	**$ 1,620,000**	**$2,000,000**	**$ 5,308,360**	
64	Preliminary feasibility studies	5/20/99 8:00	5/17/00 17:00	52	1.5	78	**Comm Develop**	**COM**	**$183,456**	**$ 275,184**	$ 300,000		**$ 575,184**	Assumed 0.5 ftes in-house per study and three studies conducted ($100K subcontracts per study)
65	Select partners for final feasibility studies	5/18/00 8:00	5/18/00 17:00	2	3.9	7.8	**Comm Develop**	**COM**	**$183,456**	**$ 27,518**			**$ 27,518**	
66	Final feasibility studies	7/3/00 8:00	6/29/01 17:00	52	1.39	72.28	**Comm Develop**	**COM**	**$183,456**	**$ 255,004**	$ 1,000,000		**$ 1,255,004**	Assumed to be the same as the cost of Gridley phase 1 activities
67	Select partners for business plan development	7/2/01 8:00	7/2/01 17:00	2	3.9	7.8	**Comm Develop**	**COM**	**$183,456**	**$ 27,518**			**$ 27,518**	
68	**Business Plans**	**7/3/01 8:00**	**1/22/04 17:00**	**133.6**		**198.08**	**Comm Develop**	**COM**	**$183,456**	**$ 698,826**	**$ 200,000**	**$ -**	**$ 898,826**	
69	**Conduct New Business Plans**	**7/3/01 8:00**	**1/22/04 17:00**	**133.6**		**198.08**	**Comm Develop**	**COM**	**$183,456**	**$ 698,826**	**$ 200,000**	**$ -**	**$ 898,826**	
70	Negotiate Legal Arrangements with Partners	7/3/01 8:00	8/27/01 17:00	8	2	16	**Comm Develop**	**COM**	**$183,456**	**$ 56,448**			**$ 56,448**	
71	Establish Feedstock/Product Contracts and Site Commitments	7/3/01 8:00	12/31/01 17:00	26	0	0	**Comm Develop**	**COM**	**$183,456**	**$ -**			**$ -**	Covered by Oak Ridge
72	Conduct PDU Testing and Data Analysis	4/4/03 8:00	10/2/03 17:00	26	6.08	158.08	**Comm Develop**	**COM**	**$183,456**	**$ 557,706**	$ 200,000		**$ 757,706**	
73	Re-evaluate Process Design and Cost Estimate	10/3/03 8:00	10/30/03 17:00	4	1	4	**Comm Develop**	**COM**	**$183,456**	**$ 14,112**			**$ 14,112**	
74	Negotiate License Agreements and Performance Guarantees	10/31/03 8:00	12/25/03 17:00	8	2	16	**Comm Develop**	**COM**	**$183,456**	**$ 56,448**			**$ 56,448**	
75	Issue New Business Plans	12/26/03 8:00	1/22/04 17:00	4	1	4	**Comm Develop**	**COM**	**$183,456**	**$ 14,112**			**$ 14,112**	
76	Select Partners for Demonstration Plant Development	1/23/04 8:00	2/19/04 17:00	4	3.9	15.6	**Comm Develop**	**COM**	**$183,456**	**$ 55,037**			**$ 55,037**	
77	**Demonstration Plants**	**2/20/04 8:00**	**12/9/05 17:00**	**94.2**		**99**	**Comm Develop**	**COM**	**$183,456**	**$ 349,272**	**$ 120,000**	**$2,000,000**	**$ 2,469,272**	
78	**Conduct New Demonstration Plant Efforts**	**2/20/04 8:00**	**12/9/05 17:00**	**94.2**		**99**	**Comm Develop**	**COM**	**$183,456**	**$ 349,272**	**$ 120,000**	**$2,000,000**	**$ 2,469,272**	
79	Finance Facility	2/20/04 8:00	6/10/04 17:00	16	0.5	8	**Comm Develop**	**COM**	**$183,456**	**$ 28,224**			**$ 28,224**	
80	Conduct Detailed Design	2/20/04 8:00	2/17/05 17:00	52	0.5	26	**Comm Develop**	**COM**	**$183,456**	**$ 91,728**	$ 100,000		**$ 191,728**	
81	Obtain Permits	6/11/04 8:00	6/9/05 17:00	52	0.5	26	**Comm Develop**	**COM**	**$183,456**	**$ 91,728**	$ 20,000		**$ 111,728**	
82	Construct Facility	6/11/04 8:00	6/9/05 17:00	52	0.5	26	**Comm Develop**	**COM**	**$183,456**	**$ 91,728**		$2,000,000	**$ 2,091,728**	
83	Start Up Facility by Year 2000	6/10/05 8:00	12/8/05 17:00	26	0.5	13	**Comm Develop**	**COM**	**$183,456**	**$ 45,864**			**$ 45,864**	
84	Commercial Operation	12/9/05 8:00	12/9/05 17:00	0		0	**Comm Develop**	**COM**	**$183,456**	**$ -**			**$ -**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
103	**Softwood-specific process integration and process development activities**	**10/1/96 8:00**	**7/29/98 17:00**	**95.4**		**136.9**	**Softwoods**	**SFT**	**$183,456**	**$ 482,983**	**$ 510,000**		**$ 992,983**	
104	**Preliminary Technology Analysis**	**10/1/96 8:00**	**12/30/96 17:00**	**13**		**10.6**	**Softwoods**	**SFT**	**$183,456**	**$ 37,397**	**$ 50,000**		**$ 87,397**	
105	**Investigate technologies**	**10/1/96 8:00**	**10/28/96 17:00**	**4**		**6**	**Softwoods**	**SFT**	**$183,456**	**$ 21,168**	**$ -**		**$ 21,168**	
106	SO2 steam explosion	10/1/96 8:00	10/28/96 17:00	4	0.13	0.5	**Softwoods**	**SFT**	**$183,456**	**$ 1,764**			$ 1,764	Estimate from Quang based on time for one fte to complete work
107	Dilute acid hydrolysis	10/1/96 8:00	10/28/96 17:00	4	0.13	0.5	**Softwoods**	**SFT**	**$183,456**	**$ 1,764**			$ 1,764	Estimate from Quang based on time for one fte to complete work
108	Concentrated acid	10/1/96 8:00	10/28/96 17:00	4	0.25	1	**Softwoods**	**SFT**	**$183,456**	**$ 3,528**			$ 3,528	Estimate from Quang based on time for one fte to complete work
109	ACOS organosolv process	10/1/96 8:00	10/28/96 17:00	4	0.25	1	**Softwoods**	**SFT**	**$183,456**	**$ 3,528**			$ 3,528	Estimate from Quang based on time for one fte to complete work
110	Enzyme production	10/1/96 8:00	10/28/96 17:00	4	0.25	1	**Softwoods**	**SFT**	**$183,456**	**$ 3,528**			$ 3,528	Estimate from Quang based on time for one fte to complete work
111	Fermentation/SHF/SSF	10/1/96 8:00	10/28/96 17:00	4	0.25	1	**Softwoods**	**SFT**	**$183,456**	**$ 3,528**			$ 3,528	Estimate from Quang based on time for one fte to complete work
112	Lignin utilization	10/1/96 8:00	10/28/96 17:00	4	0.25	1	**Softwoods**	**SFT**	**$183,456**	**$ 3,528**			$ 3,528	Estimate from Quang based on time for one fte to complete work
113	**Model 5 process options for softwoods**	**10/29/96 8:00**	**12/23/96 17:00**	**8**		**2.6**	**Softwoods**	**SFT**	**$183,456**	**$ 9,173**	**$ 50,000**		**$ 59,173**	
114	Complete process & economic model	10/29/96 8:00	11/18/96 17:00	3	0.87	2.6	**Softwoods**	**SFT**	**$183,456**	**$ 9,173**	$ 50,000		$ 59,173	Actual time required to finish model is one year (compared to plan of 3 wks). In-house cost estimated as 0.05 for 1 yr.

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
115	Option A	11/19/96 8:00	11/25/96 17:00	1	0	0	**Softwoods**	**SFT**	**$ 183,456**	**$ -**			$ -	Subcontract and in-house cost for process modeling includes costs for Options A through E
116	Option B	11/26/96 8:00	12/2/96 17:00	1	0	0	**Softwoods**	**SFT**	**$ 183,456**	**$ -**			$ -	Subcontract and in-house cost for process modeling includes costs for Options A through E
117	Option C	12/3/96 8:00	12/9/96 17:00	1	0	0	**Softwoods**	**SFT**	**$ 183,456**	**$ -**			$ -	Subcontract and in-house cost for process modeling includes costs for Options A through E
118	Option D	12/10/96 8:00	12/16/96 17:00	1	0	0	**Softwoods**	**SFT**	**$ 183,456**	**$ -**			$ -	Subcontract and in-house cost for process modeling includes costs for Options A through E
119	Option E	12/17/96 8:00	12/23/96 17:00	1	0	0	**Softwoods**	**SFT**	**$ 183,456**	**$ -**			$ -	Subcontract and in-house cost for process modeling includes costs for Options A through E
120	Identify technology gaps	12/24/96 8:00	12/30/96 17:00	1	2	2	**Softwoods**	**SFT**	**$ 183,456**	**$ 7,056**			$ 7,056	Subcontract and in-house cost for process modeling includes costs for Options A through E
121	**Fill Technology Gaps for Softwoods**	**12/31/96 8:00**	**10/7/97 17:00**	**40.2**		**102.7**	**Softwoods**	**SFT**	**$ 183,456**	**$ 362,326**	**$ 310,000**		**$ 672,326**	
122	Revise softwoods technology plan	12/31/96 8:00	1/6/97 17:00	1	1	1	**Softwoods**	**SFT**	**$ 183,456**	**$ 3,528**			$ 3,528	
123	Subcontract or CRADA with UBC	1/7/97 8:00	10/6/97 17:00	39	0.1	3.9	**Softwoods**	**SFT**	**$ 183,456**	**$ 13,759**	$ 110,000		$ 123,759	According to Quang subcontracts #2 and #3 will not be done. But, I have left them as part of the baseline plan from 10/96
124	Subcontract #2	1/7/97 8:00	10/6/97 17:00	39	0.1	3.9	**Softwoods**	**SFT**	**$ 183,456**	**$ 13,759**	$ 100,000		$ 113,759	
125	Subcontract #3	1/7/97 8:00	10/6/97 17:00	39	0.1	3.9	**Softwoods**	**SFT**	**$ 183,456**	**$ 13,759**	$ 100,000		$ 113,759	
126	**Pretreatment & fermentation work at NREL**	**1/7/97 8:00**	**10/6/97 17:00**	**39**		**80**	**Softwoods**	**SFT**	**$ 183,456**	**$ 282,240**	**$ -**		**$ 282,240**	

ID	Task Name	Start	Finish	Duration (	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
262	**Fermentation Organism Development**	**10/1/96 8:00**	**9/27/01 17:00**	**260.6**		**2054**	**Fermentation Researcher**	**FER**	**$ 183,456**	**$ 7,246,512**	**$ 2,075,000**	**$ -**	**$ 9,321,512**	
263	**Develop Zymomonas Organism for use in year 2000 waste to ethanol facility**	**10/1/96 8:00**	**9/26/00 17:00**	**208.2**		**1118**	**Fermentation Researcher**	**FER**	**$ 183,456**	**$ 3,944,304**	**$ 1,000,000**	**$ -**	**$ 4,944,304**	
264	Evaluate new new Zymomonas strains	10/1/96 8:00	9/29/97 17:00	52	2.5	130	Fermentation Researcher	FER	$ 183,456	$ 458,640			$ 458,640	
265	Select strains for hand-off to integration studies	9/30/97 8:00	9/30/97 17:00	0		0	Fermentation Researcher	FER	$ 183,456	$ -			$ -	
266	Develop further improvements to Zymomonas organism	9/30/97 8:00	9/28/98 17:00	52	2	104	Fermentation Researcher	FER	$ 183,456	$ 366,912			$ 366,912	
267	Hand-off improved Zymomonas strain for pilot scale demonstration work with industrial partner	9/29/98 8:00	9/29/98 17:00	1		0	Fermentation Researcher	FER	$ 183,456	$ -			$ -	
268	Investigate new approaches to improving Zymomonas strain	10/1/96 8:00	9/29/97 17:00	52	4	208	Fermentation Researcher	FER	$ 183,456	$ 733,824	$ 200,000		$ 933,824	
269	Begin making metabolic enhancements of Zymomonas	9/30/97 8:00	9/27/99 17:00	104	2	208	Fermentation Researcher	FER	$ 183,456	$ 733,824	$ 300,000		$ 1,033,824	
270	Implement strategies to improve robustness of Zymomonas strain	9/30/97 8:00	9/27/99 17:00	104	2.5	260	Fermentation Researcher	FER	$ 183,456	$ 917,280	$ 300,000		$ 1,217,280	
271	Develop a "super" Zymomonas strain with desired robustness and sugar utilization characteristics	9/28/99 8:00	9/25/00 17:00	52	4	208	Fermentation Researcher	FER	$ 183,456	$ 733,824	$ 200,000		$ 933,824	
272	Hand-off advanced Zymomonas strains to industrial partner for use in commercial facility	9/26/00 8:00	9/26/00 17:00	0		0	Fermentation Researcher	FER	$ 183,456	$ -			$ -	
273	**Develop Zymomonas Organism for use in year 2005 switchgrass to ethanol facility**	**9/27/00 8:00**	**9/26/01 17:00**	**52.2**		**208**	**Fermentation Researcher**	**FER**	**$ 183,456**	**$ 733,824**	**$ 200,000**	**$ -**	**$ 933,824**	
274	Make adjustments switchgrass	9/27/00 8:00	9/25/01 17:00	52	4	208	Fermentation Researcher	FER	$ 183,456	$ 733,824	$ 200,000		$ 933,824	
275	Hand-off switchgrass Zymomonas strain to EPD for integration studies	9/26/01 8:00	9/26/01 17:00	0		0	Fermentation Researcher	FER	$ 183,456	$ -			$ -	
276	**Develop a Lactobacillus strain for improved performance and robustness**	**10/1/96 8:00**	**9/27/00 17:00**	**208.4**		**572**	**Fermentation Researcher**	**FER**	**$ 183,456**	**$ 2,018,016**	**$ 675,000**	**$ -**	**$ 2,693,016**	
277	Re-initiate work on lactobacillus	10/1/96 8:00	9/29/97 17:00	52	1	52	Fermentation Researcher	FER	$ 183,456	$ 183,456	$ 75,000		$ 258,456	
278	Develop an ethanol producing lactobacillus	9/30/97 8:00	9/28/98 17:00	52	2	104	Fermentation Researcher	FER	$ 183,456	$ 366,912	$ 200,000		$ 566,912	
279	Hand-off lactobacillus to EPD for integration and PDU studies	9/29/98 8:00	9/29/98 17:00	0		0	Fermentation Researcher	FER	$ 183,456	$ -			$ -	
280	Assess and improve lactobacillus strains	9/30/98 8:00	9/26/00 17:00	104	4	416	Fermentation Researcher	FER	$ 183,456	$ 1,467,648	$ 400,000		$ 1,867,648	
281	Hand-off lactobacillus organism to EPD for integration and pilot scale studies	9/27/00 8:00	9/27/00 17:00	0		0	Fermentation Researcher	FER	$ 183,456	$ -			$ -	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
127	Dilute acid pretreatment	1/7/97 8:00	10/6/97 17:00	39	0.77	30	**Softwoods**	**SFT**	**$ 183,456**	**$ 105,840**			$ 105,840	5 FTEs assigned to do 30 man-weeks of work
128	SO2 Steam explosion	1/7/97 8:00	10/6/97 17:00	39	0.26	10	**Softwoods**	**SFT**	**$ 183,456**	**$ 35,280**			$ 35,280	5 FTEs assigned to do 10 man -weeks of work
129	C6 Fermentation R&D	1/7/97 8:00	10/6/97 17:00	39	1.03	40	**Softwoods**	**SFT**	**$ 183,456**	**$ 141,120**			$ 141,120	2 FTEs assigned to do 40 man-weeks of work
130	Preliminary assessment of integrated technologies completed	10/7/97 8:00	10/7/97 17:00	1	10	10	**Softwoods**	**SFT**	**$ 183,456**	**$ 35,280**			$ 35,280	2 FTEs assinged to do 10 man-weeks of work in 5 weeks. This is shown as a one week activity in plan
131	**Process Selection and PDU Testing**	**10/8/97 8:00**	**7/29/98 17:00**	**42.2**		**23.6**	Softwoods	**SFT**	**$ 183,456**	**$ 83,261**	**$ 150,000**		**$ 233,261**	
132	Revise Process Models	10/8/97 8:00	10/21/97 17:00	2	1.3	2.6	**Softwoods**	**SFT**	**$ 183,456**	**$ 9,173**	$ 50,000		$ 59,173	New estimate for time is 26 weeks instead of 2 weeks. This would increase the in-house manpower which is 10% of an FTE over the duration
133	Select Process for further development	10/22/97 8:00	10/28/97 17:00	1	1	1	**Softwoods**	**SFT**	**$ 183,456**	**$ 3,528**			$ 3,528	
134	Subcontract #4	10/29/97 8:00	7/28/98 17:00	39	0.51	20	**Softwoods**	**SFT**	**$ 183,456**	**$ 70,560**	$ 100,000		$ 170,560	Vendor testing requiring one fte for 20 weeks
135	Integrated process for softwood to ethanol technology available for commercial development by industry	7/29/98 8:00	7/29/98 17:00	1		0	**Softwoods**	**SFT**	**$ 183,456**	**$ -**			$ -	

ID	Task Name	Start	Finish	Duration (	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
282	**Develop Lactobacillus strain for use in year 2005 switchgrass to ethanol facility**	**9/28/00 8:00**	**9/27/01 17:00**	**52.2**		**156**	**Fermentation Researcher**	**FER**	**$ 183,456**	**$ 550,368**	**$ 200,000**	**$ -**	**$ 750,368**	
283	Make adjustments for switchgrass sugars as needed	9/28/00 8:00	9/26/01 17:00	52	3	156	**Fermentation Researcher**	**FER**	**$ 183,456**	$ 550,368	$ 200,000		**$ 750,368**	
284	Hand-off switchgrass Lactobacillus strain to EPD for testing	9/27/01 8:00	9/27/01 17:00	0		0	**Fermentation Researcher**	**FER**	**$ 183,456**	$ -			**$ -**	
285	**Direct Microbial Conversion Strain Development**	**10/1/96 8:00**	**10/2/03 17:00**	**365.6**		**391.1**	**Fermentation Researcher**	**FER**	**$ 183,456**	**$ 1,379,801**	**$ -**	**$ -**	**$ 1,379,801**	
286	**Develop cost effective Zymomonas strains for DMC process**	**10/1/96 8:00**	**10/2/03 17:00**	**365.6**		**391.1**	**Fermentation Researcher**	**FER**	**$ 183,456**	**$ 1,379,801**	**$ -**	**$ -**	**$ 1,379,801**	
287	Acquire or produce cDNA clone of best beta-glucosidase or cellobiase	10/1/96 8:00	10/1/97 17:00	52.4		0	**Fermentation Researcher**	**FER**	**$ 183,456**	$ -			**$ -**	
288	Clone cellobiase in best "Z" using best expression vectors	10/2/97 8:00	10/1/98 17:00	52.2	0.5	26.1	**Fermentation Researcher**	**FER**	**$ 183,456**	$ 92,081			**$ 92,081**	
289	Deliver cellobiose fermenting "Z" to EPT for testing	10/2/98 8:00	10/2/98 17:00	0		0	**Fermentation Researcher**	**FER**	**$ 183,456**	$ -			**$ -**	
290	Develop integrated transformation system for Z, using cellobiase gene	10/5/98 8:00	10/1/01 17:00	156.2	1	156.2	**Fermentation Researcher**	**FER**	**$ 183,456**	$ 551,074			**$ 551,074**	
291	Clone rEI and rCBHI in best "Z" or Lactobacillus	10/2/01 8:00	10/1/03 17:00	104.4	2	208.8	**Fermentation Researcher**	**FER**	**$ 183,456**	$ 736,646			**$ 736,646**	
292	Deliver engineered "Z" or Lactobacillus to EPT for testing	10/2/03 8:00	10/2/03 17:00	0		0	**Fermentation Researcher**	**FER**	**$ 183,456**	$ -			**$ -**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
136	**Process Integration and Process Development**	**10/1/96 8:00**	**4/3/03 17:00**	**339.6**		**2807.5**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 9,904,860**	**$ 65,000**	**$ 540,000**	**$ 10,509,860**	
137	**Provide commercial development facility capabilities to support industrial partners**	**10/1/96 8:00**	**3/25/98 17:00**	**77.4**		**255.5**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 901,404**	**$ 40,000**	**$ 400,000**	**$ 1,341,404**	
138	**Demonstrate an integrated process for ethanol from cellulose in a mini-pilot plant system**	**10/1/96 8:00**	**3/18/97 17:00**	**121**		**90**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 317,520**	**$ 20,000**	**$ -**	**$ 337,520**	
139	Establish complete integrated process flow diagram for minipilot plant	10/1/96 8:00	10/28/96 17:00	4	0.5	2	**Proc Dev**	**EPD**	**$ 183,456**	**$ 7,056**			**$ 7,056**	
140	Prove that aseptic conditions can be maintained in the biochemical conversion unit	10/29/96 8:00	11/25/96 17:00	4	2	8	**Proc Dev**	**EPD**	**$ 183,456**	**$ 28,224**			**$ 28,224**	
141	Obtain approval to operate the mini-pilot plant using a genetically engineered microorganism	11/26/96 8:00	12/23/96 17:00	4	2.5	10	**Proc Dev**	**EPD**	**$ 183,456**	**$ 35,280**			**$ 35,280**	
142	Design, procure and test ion exchange equipment for hydrolysate conditioning	10/1/96 8:00	1/6/97 17:00	14	3	42	**Proc Dev**	**EPD**	**$ 183,456**	**$ 148,176**	$ 20,000		**$ 168,176**	
143	Ready Sunds reactor to produce pretreated sawdust for integrated demonstration	1/7/97 8:00	2/3/97 17:00	4	2	8	**Proc Dev**	**EPD**	**$ 183,456**	**$ 28,224**			**$ 28,224**	
144	Run process qualifier technology demonstration	2/4/97 8:00	3/3/97 17:00	4	4	16	**Proc Dev**	**EPD**	**$ 183,456**	**$ 56,448**			**$ 56,448**	
145	Document process qualifier demonstration	3/4/97 8:00	3/17/97 17:00	2	2	4	**Proc Dev**	**EPD**	**$ 183,456**	**$ 14,112**			**$ 14,112**	
146	Mini-pilot biochemical conversion unit available for commercial development	3/18/97 8:00	3/18/97 17:00	0		0	**Proc Dev**	**EPD**	**$ 183,456**	**$ -**			**$ -**	
147	Design full pilot plant scale detoxification equipment	10/1/96 8:00	6/9/97 17:00	36	1.5	54	**Proc Dev**	**EPD**	**$ 183,456**	**$ 190,512**		$ 400,000	**$ 590,512**	
148	Install full pilot plant scale detoxification equipment	6/10/97 8:00	8/18/97 17:00	10	2.5	25	**Proc Dev**	**EPD**	**$ 183,456**	**$ 88,200**			**$ 88,200**	
149	Test and modify full pilot scale detoxification equipment	8/19/97 8:00	12/22/97 17:00	18	3	54	**Proc Dev**	**EPD**	**$ 183,456**	**$ 190,512**			**$ 190,512**	
150	Detoxification process available for pilot scale commercial development	12/23/97 8:00	12/23/97 17:00	0		0	**Proc Dev**	**EPD**	**$ 183,456**	**$ -**			**$ -**	
151	Design SSCF system for pilot plant demonstration based on experimental results available	12/24/97 8:00	3/24/98 17:00	13	0.5	6.5	**Proc Dev**	**EPD**	**$ 183,456**	**$ 22,932**			**$ 22,932**	
152	Evaluate spent solids for combustion value	12/24/97 8:00	3/24/98 17:00	13	0.5	6.5	**Proc Dev**	**EPD**	**$ 183,456**	**$ 22,932**	$ 10,000		**$ 32,932**	
153	Investigate the impacts of gypsum on the bioethanol process prior to pilot plant testing	12/24/97 8:00	3/24/98 17:00	13	1.5	19.5	**Proc Dev**	**EPD**	**$ 183,456**	**$ 68,796**	$ 10,000		**$ 78,796**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
154	Pilot scale testing capability available for use by commercial partners	3/25/98 8:00	3/25/98 17:00	0		0	Proc Dev	EPD	$ 183,456	$ -			$ -	
155	**Provide integrated process technology for commercial development meeting the cost target of $1.13 /gal ethanol**	**10/1/96 8:00**	**12/10/98 17:00**	**114.6**		**1148**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 4,050,144**	**$ 25,000**	**$ 140,000**	**$ 4,215,144**	
156	**Develop cellulase enzyme production technology utilizing hydrolysate and pretreated solids**	**10/1/96 8:00**	**9/15/98 17:00**	**102.2**		**459**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 1,619,352**	**$ 25,000**	**$ 140,000**	**$ 1,784,352**	
157	Establish cellulase production on hydrolysate and pretreated solids	10/1/96 8:00	9/1/97 17:00	48	4.5	216	Proc Dev	EPD	$ 183,456	$ 762,048		$ 100,000	$ 862,048	
158	Improve cellulase production on hydrolysate and pretreated solids based on induction protocol studies	9/2/97 8:00	9/14/98 17:00	54	4.5	243	Proc Dev	EPD	$ 183,456	$ 857,304	$ 25,000	$ 40,000	$ 922,304	
159	Cellulase enzyme production technology available for commercial development	9/15/98 8:00	9/15/98 17:00	0		0	Proc Dev	EPD	$ 183,456	$ -			$ -	
160	**Improve integrated process performance to achieve cost target for year 2000 deployment**	**10/1/96 8:00**	**12/10/98 17:00**	**114.6**		**689**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 2,430,792**	**$ -**	**$ -**	**$ 2,430,792**	
161	Produce pretreated and detoxified materials to meet team experimental needs	10/1/96 8:00	1/6/97 17:00	14	1.5	21	Proc Dev	EPD	$ 183,456	$ 74,088			$ 74,088	
162	Improve pretreatment to increase cellulose digestibility and hemicellulose sugar yield	10/1/96 8:00	3/31/97 17:00	26	3	78	Proc Dev	EPD	$ 183,456	$ 275,184			$ 275,184	
163	Develop Zymomonas strain adapted to 100 % hydrolysate	10/1/96 8:00	3/17/97 17:00	24	1	24	Proc Dev	EPD	$ 183,456	$ 84,672			$ 84,672	
164	Complete detoxification process development at the bench scale	10/1/96 8:00	8/4/97 17:00	44	3	132	Proc Dev	EPD	$ 183,456	$ 465,696			$ 465,696	
165	Provide data on applicability of detoxification to various feedstocks	8/5/97 8:00	8/5/97 17:00	0		0	Proc Dev	EPD	$ 183,456	$ -			$ -	
166	Investigate SSCF performance by consideration of alternate process configurations	4/1/97 8:00	6/23/97 17:00	12	3	36	Proc Dev	EPD	$ 183,456	$ 127,008			$ 127,008	
167	Investigate SSCF performance utilizing improved pretreatment, best detoxification and best performing Zymomonas	10/1/97 8:00	5/12/98 17:00	32	4	128	Proc Dev	EPD	$ 183,456	$ 451,584			$ 451,584	
168	Improved process technology ready for review and generation of new improvement projects	5/13/98 8:00	5/13/98 17:00	0		0	Proc Dev	EPD	$ 183,456	$ -			$ -	
169	Prioritized improvement projects carried out	5/14/98 8:00	12/9/98 17:00	30	9	270	Proc Dev	EPD	$ 183,456	$ 952,560			$ 952,560	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
170	Integrated biomass to ethanol technology meeting year 2000 performance available for commercial deployment	12/10/98 8:00	12/10/98 17:00	0		0	Proc Dev	EPD	$ 183,456	$ -			$ -	
171	**Test incremental improvements under integrated process conditions**	**9/30/98 8:00**	**4/3/03 17:00**	**235.4**		**1404**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 4,953,312**	**$ -**	**$ -**	**$ 4,953,312**	
172	**First roll-out of improvements in technology for near term waste feedstocks**	**9/30/98 8:00**	**12/1/99 17:00**	**61.2**		**468**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 1,651,104**	**$ -**	**$ -**	**$ 1,651,104**	
173	Test first generation countercurrent prehydrolysis technology in integrated process at the bench scale	12/2/98 8:00	11/30/99 17:00	52	3	156	Proc Dev	EPD	$ 183,456	$ 550,368			$ 550,368	
174	Test Phase I genetically engineered cellulase system in integrated process at the bench scale	10/7/98 8:00	10/5/99 17:00	52	3	156	Proc Dev	EPD	$ 183,456	$ 550,368			$ 550,368	
175	Test improved Zymomonas strain in integrated process at the bench scale	9/30/98 8:00	9/28/99 17:00	52	3	156	Proc Dev	EPD	$ 183,456	$ 550,368			$ 550,368	
176	Documented improvements available for commercial deployment by industrial partners	12/1/99 8:00	12/1/99 17:00	0		0	Proc Dev	EPD	$ 183,456	$ -			$ -	
177	**Second roll-out of improvements in technology for near term waste feedstocks**	**9/27/00 8:00**	**1/8/02 17:00**	**67**		**390**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 1,375,920**	**$ -**	**$ -**	**$ 1,375,920**	
178	Test lignin utilization technology	1/9/01 8:00	1/7/02 17:00	52	1.5	78	Proc Dev	EPD	$ 183,456	$ 275,184			$ 275,184	
179	Test second generation countercurrent prehydrolysis technology at the bench scale	10/5/00 8:00	10/3/01 17:00	52	3	156	Proc Dev	EPD	$ 183,456	$ 550,368			$ 550,368	
180	Test "super" Zymomonas strain (robust) and/or Lactobacillus at the bench scale	9/27/00 8:00	9/25/01 17:00	52	3	156	Proc Dev	EPD	$ 183,456	$ 550,368			$ 550,368	
181	Improved low-value feedstock technology available for commercial development by industry	1/8/02 8:00	1/8/02 17:00	0		0	Proc Dev	EPD	$ 183,456	$ -			$ -	
182	**Develop integrated process for switchgrass conversion that meets a target of $0.90/gal**	**9/28/01 8:00**	**4/3/03 17:00**	**79**		**546**	**Proc Dev**	**EPD**	**$ 183,456**	**$ 1,926,288**	**$ -**	**$ -**	**$ 1,926,288**	
183	Test improvements in fermentor strains at the bench scale	9/28/01 8:00	9/26/02 17:00	52	3	156	Proc Dev	EPD	$ 183,456	$ 550,368			$ 550,368	
184	Test Phase II cellulase system at the bench scale	10/4/01 8:00	10/2/02 17:00	52	3	156	Proc Dev	EPD	$ 183,456	$ 550,368			$ 550,368	
185	Integrate switchgrass to ethanol process at smallest possible scale	4/4/02 8:00	4/2/03 17:00	52	4.5	234	Proc Dev	EPD	$ 183,456	$ 825,552			$ 825,552	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
186	Switchgrass technology available for commercial development by industrial partners	4/3/03 8:00	4/3/03 17:00	0		0	**Proc Dev**	**EPD**	**$ 183,456**	**$ -**			**$ -**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
226	**Enzyme Technology R&D**	**10/1/96 8:00**	**10/1/03 17:00**	**365.4**		**2442.844**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 8,618,354**	**$ 2,179,615**	**$ -**	**$ 10,797,969**	
227	**Near Term Enzyme R&D**	**10/1/96 8:00**	**10/5/98 17:00**	**105**		**45.084**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 159,056**	**$ -**	**$ -**	**$ 159,056**	
228	T. reesei: Decrease cellulase cost by optimizing induction protocols	10/1/96 8:00	6/30/97 17:00	39	0.5	**19.5**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 68,796**			**$ 68,796**	Finish is now 8/30/97. Work calculated as equivalent of 0.375 fte's for a full year. For a 39 week period this corresponds to 0.5 ftes
229	Deliver new protocols to EPD	7/1/97 8:00	7/1/97 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
230	T. reesei: Determine effects of induction protocols on component enzymes	7/2/97 8:00	10/2/98 17:00	65.6	0.39	**25.584**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 90,260**			**$ 90,260**	Starts on 9/1 goes for 13 months to end 10/1/98. The level of effort is 0.45. For the scheduled 65.6 wks this equates to 0.386
231	Report correlation between T. reesei induction and enzyme mix	10/5/98 8:00	10/5/98 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
232	**Mid Term Enzyme R&D**	**10/1/96 8:00**	**10/1/03 17:00**	**365.4**		**2397.76**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 8,459,297**	**$ 2,179,615**	**$ -**	**$ 10,638,913**	
233	**Develop cost effective enzyme system for pretreated SG**	**10/1/96 8:00**	**10/1/03 17:00**	**365.4**		**2397.76**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 8,459,297**	**$ 2,179,615**	**$ -**	**$ 10,638,913**	
234	Phase I: Improve action of EI on pSG using site-directed mutagenesis	10/1/96 8:00	10/1/98 17:00	104.6	2.16	**225.936**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 797,102**			**$ 797,102**	
235	Phase I: Increase Topt and process tolerance of CBH I using SDM	2/3/97 8:00	10/5/98 17:00	87.2	1.7	**148.24**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 522,991**			**$ 522,991**	
236	Perform substrate/cellulose binding domain modeling for CBHI	12/2/96 8:00	9/30/98 17:00	95.6	0.1	**9.56**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 33,728**	$ 150,000		**$ 183,728**	In-house staff is for monitoring subcontracts
237	Phase I: Increase Topt and process tolerance of E3 using SDM	12/2/96 8:00	9/30/98 17:00	95.6	0.05	**4.78**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 16,864**	$ 200,000		**$ 216,864**	In-house staff is for monitoring subcontracts
238	Provide high resolution x-ray structure for E3 and clones of EI	12/2/96 8:00	9/30/98 17:00	95.6	0.03	**2.868**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 10,118**	$ 200,000		**$ 210,118**	
239	Report K Milestone describing cellulase improvement by SDM	10/1/98 8:00	10/1/98 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
240	Deliver Phase I engineered cellulase system to EPD for testing	10/6/98 8:00	10/6/98 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
241	DECISION: Pick plant or submerged culture expression-continue w choice	10/7/98 8:00	10/7/98 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
242	Develop strategy to improve active site performance of cellulases	10/1/97 8:00	9/30/98 17:00	52.2	0.5	**26.1**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 92,081**	$ 5,000		**$ 97,081**	This is a group effort for enzyme researchers. Not just one person. A small amount of consulting time is anticipated
243	Phase II: Increase specific activity of CBHI on pSG using SDM	**##########**	10/1/01 17:00	154	2	**308**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 1,086,624**			**$ 1,086,624**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
244	Phase II: Increase specific activity of E3 on pSG using SDM	##########	9/28/01 17:00	153.8	2	**307.6**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 1,085,213**			**$ 1,085,213**	
245	Deliver Phase II engineered cellulase system w accessory enz to EPD for testing	10/2/01 8:00	10/2/01 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
246	DECISION: Pick enzymes or DMC	10/3/01 8:00	10/3/01 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
247	Produce rEI, rCBHI, and rE3 in 1st Gen plants	12/2/96 8:00	12/3/97 17:00	52.6	0.1	**5.26**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 18,557**	$ 200,000		**$ 218,557**	In-house staff is for monitoring subcontracts
248	Evaluate field tests and enzyme recovery schemes	12/4/97 8:00	10/2/98 17:00	217	0.5	**108.5**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 382,788**	$ 5,000		**$ 387,788**	
249	Produce rEI, rCBHI, and rE3 in 2nd Gen plant systems	10/7/98 8:00	8/7/01 17:00	148	0.1	**14.8**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 52,214**	$ 284,615		**$ 336,830**	In-house staff is for monitoring subcontracts. Subcontracts are estimated at 100,000 per year for the duration of the task
250	Produce improved rEI, rCBHI, and rE3 in best field crops	10/2/01 8:00	10/2/02 17:00	52.4	0.1	**5.24**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 18,487**	$ 250,000		**$ 268,487**	In-house staff is for monitoring subcontracts
251	Evaluate field tests and enzyme recovery schemes	10/3/02 8:00	9/30/03 17:00	51.8	0.5	**25.9**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 91,375**	$ 5,000		**$ 96,375**	
252	Deliver technology for plant produced cellulases to EPD for modeling and testing	10/1/03 8:00	10/1/03 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
253	Provide purified accessory enz for testing at NREL	3/3/97 8:00	###########	35	1.5	**52.5**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 185,220**			**$ 185,220**	
254	Determine utility of accessory enz (xylanases, cellodextrinases, etc) for hydrolysis of pSG	11/3/97 8:00	10/5/98 17:00	48.2	0.1	**4.82**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 17,005**	$ 180,000		**$ 197,005**	Subcontracts valued at $90K for each of two years
255	Improve Topt and process tolerance of accessory enzymes by SDM	10/6/98 8:00	9/17/01 17:00	154	2	**308**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 1,086,624**			**$ 1,086,624**	
256	Produce rEI, rCBHI, and E3 in submerged culture (Aspergillus, Trichoderma, Pichia)	10/1/97 8:00	9/30/98 17:00	52.2	0.5	**26.1**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 92,081**	$ 300,000		**$ 392,081**	In-house support for subcontract requires lab support as well as monitoring. Subcontracts valued at $150K for each of two years.
257	Produce Phase I rEI, rCBHI, rE3, and/or accessory enzymes in submerged culture	10/6/98 8:00	10/6/99 17:00	52.4	0.5	**26.2**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 92,434**	$ 150,000		**$ 242,434**	In-house support for subcontract requires lab support as well as monitoring
258	Evaluate Gen II submerged culture production technologies with industry	10/7/99 8:00	10/2/01 17:00	103.8	0.5	**51.9**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 183,103**	$ 250,000		**$ 433,103**	
259	Deliver mature technology for submerged culture production to EPD for modeling and testing	10/3/01 8:00	10/3/01 17:00	0		**0**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ -**			**$ -**	
260	Evaluate new engineered cellulase/accessory enz systems as prepared	10/1/96 8:00	9/28/01 17:00	260.8	1.41	**367.728**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 1,297,344**			**$ 1,297,344**	

ID	Task Name	Start	Finish	Duration	FTEs	Work (wks)	Resource Name	INIT	Std Rate	In-House Cost	Subcontracts	Capital	Total	Comments
261	Evaluate enzymes expressed from best plant and/or submerged culture systems	10/1/96 8:00	11/2/98 17:00	109	3.37	**367.728**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 1,297,344**			**$ 1,297,344**	Made assumption that level of effort is same as for task 260
285	**Direct Microbial Conversion Strain Development**	**10/1/96 8:00**	**10/2/03 17:00**	**365.6**		**52.4**	**Enzyme Research**	**ENZ**	**$ 183,456**	**$ 184,867**	**$ -**	**$ -**	**$ 184,867**	
286	**Develop cost effective Zymomonas strains for DMC process**	**10/1/96 8:00**	**10/2/03 17:00**	**365.6**		**52.4**			**$ 183,456**	**$ 184,867**	**$ -**	**$ -**	**$ 184,867**	
287	Acquire or produce cDNA clone of best beta-glucosidase or cellobiase	10/1/96 8:00	10/1/97 17:00	52.4	1	52.4			**$ 183,456**	**$ 184,867**			**$ 184,867**	
288	Clone cellobiase in best "Z" using best expression vectors	10/2/97 8:00	10/1/98 17:00	52.2					**$ 183,456**	**$ -**			**$ -**	
289	Deliver cellobiose fermenting "Z" to EPT for testing	10/2/98 8:00	10/2/98 17:00	0					**$ 183,456**	**$ -**			**$ -**	
290	Develop integrated transformation system for Z, using cellobiase gene	10/5/98 8:00	10/1/01 17:00	156.2					**$ 183,456**	**$ -**			**$ -**	
291	Clone rEI and rCBHI in best "Z" or Lactobacillus	10/2/01 8:00	10/1/03 17:00	104.4					**$ 183,456**	**$ -**			**$ -**	
292	Deliver engineered "Z" or Lactobacillus to EPT for testing	10/2/03 8:00	10/2/03 17:00	0					**$ 183,456**	**$ -**			**$ -**	

Calculation of Rates

Item	Cost per FTE
Loaded labor	$150,000.00
ODCs	$ 24,000.00
Matl Handling	$ 720.00
Subtotal	$174,720.00
Total	$183,456.00

MH	3%
Fee	5%

Hourly Rate $ 88.20

10. Critical Path Analysis of Near Term Technology Deployment Goal

We have used Microsoft Project™'s critical path analysis capability to assess where the critical path is for meeting the near term deployment goal in the year 2000. In addition to running the software to evaluate the critical path, we inspected the plan independently to make sure that the path identified by the software made sense.

Microsoft Project™ identifies the critical path as the sequence of tasks which must finish on time in order to for the project to meet its scheduled deadline. In other word, the critical path includes all tasks which have no slack. In this analysis, we have adjusted the definition of the critical path so that it includes any task that has less than 100 days of slack. In a plan that covers such a long time frame, it makes no sense to only look at tasks that have absolutely no float.

One of the problems with utilizing Microsoft Project™ to identify a critical path is that it cannot deal with multiple deadlines or goals in the same project. The software only recognizes the critical path for completing the latest schedule activity in the plan.

Therefore, in order to look at the critical path for only the year 2000, the plan was modified to reflect only those activities that pertain to the near term goal. After modifying the plan, the tasks were color coded to show critical path activities in red and non critical activities in blue.

10.1 Baseline Plan

For the original baseline plan (prior to resource leveling the plan), we identified a series of critical items in the plan. These include:

- Partnership development activities for softwood technology and the Delta-T CRADA
- The PDU testing and negotiations steps in business plan development
- All start up and construction aspects of the demonstration plant
- The entire softwood technology development effort under core technology
- Development of detoxification technology
- Integrated testing of the final SSCF process

Business plan activities and design and construction of the demonstration plant will always be on the critical path to the final deployment goal. As the definition for critical tasks is expanded to include "non zero" float activities, integration activities become pivotal. These are the types of activities that we would expect to be critical. It shows that the basic plan itself has sound logic, though it is not well aligned with our current resource assignments.

10.2 *Resource-Leveled Plan*

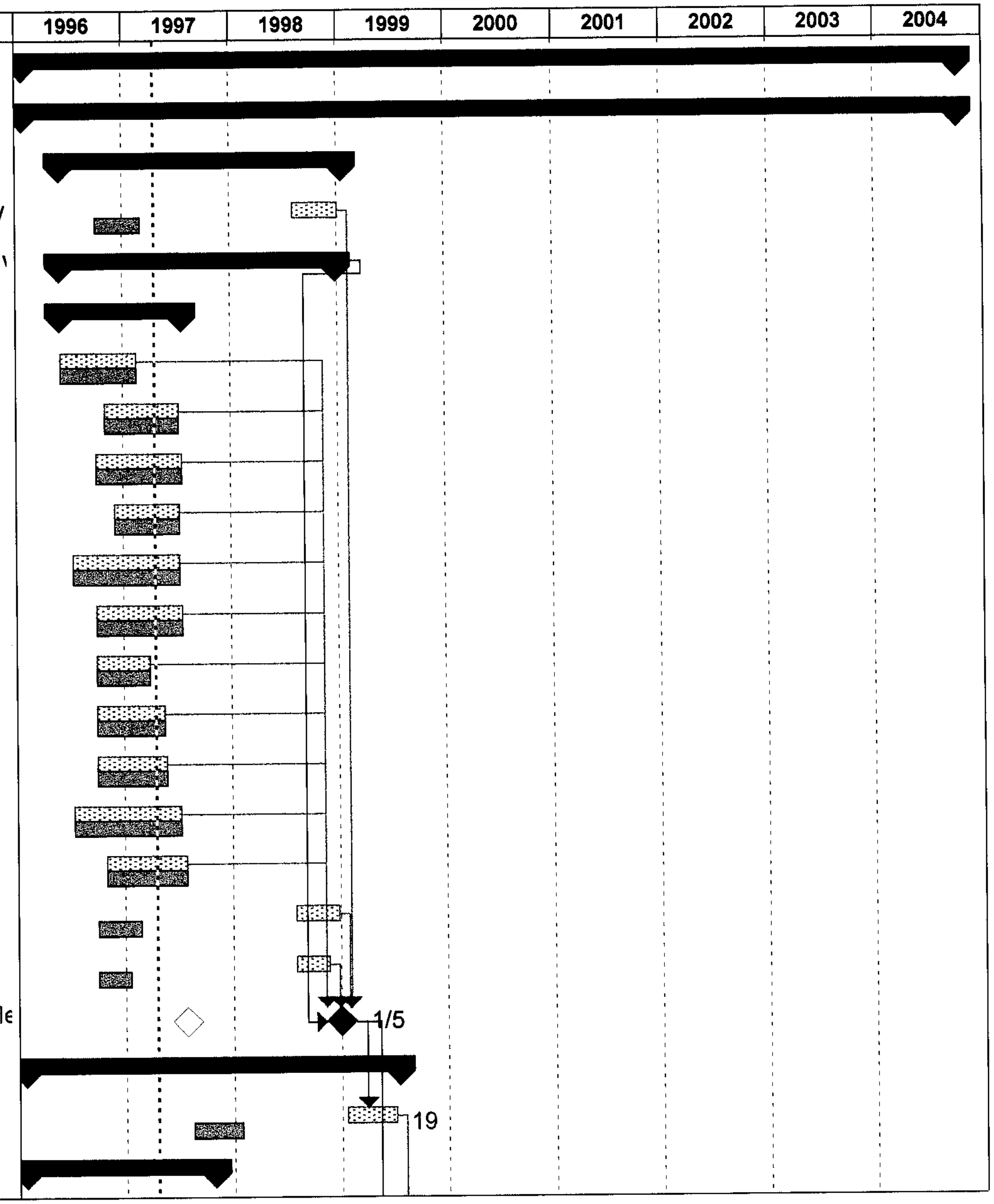
The resource-leveled plan only shows the final construction and permitting as being critical. This is telling us that our resource assignments are completely out of line. The current resource assignments lead to a situation in which everything in the R&D and partnership plans have excessive slack. This is a sign of a very inefficient plan.

Figure 24: Ethanol Multi-Year Technical Plan: Critical Path Analysis for Near Term Deployment in Baseline Plan

Shown on next 6 pages

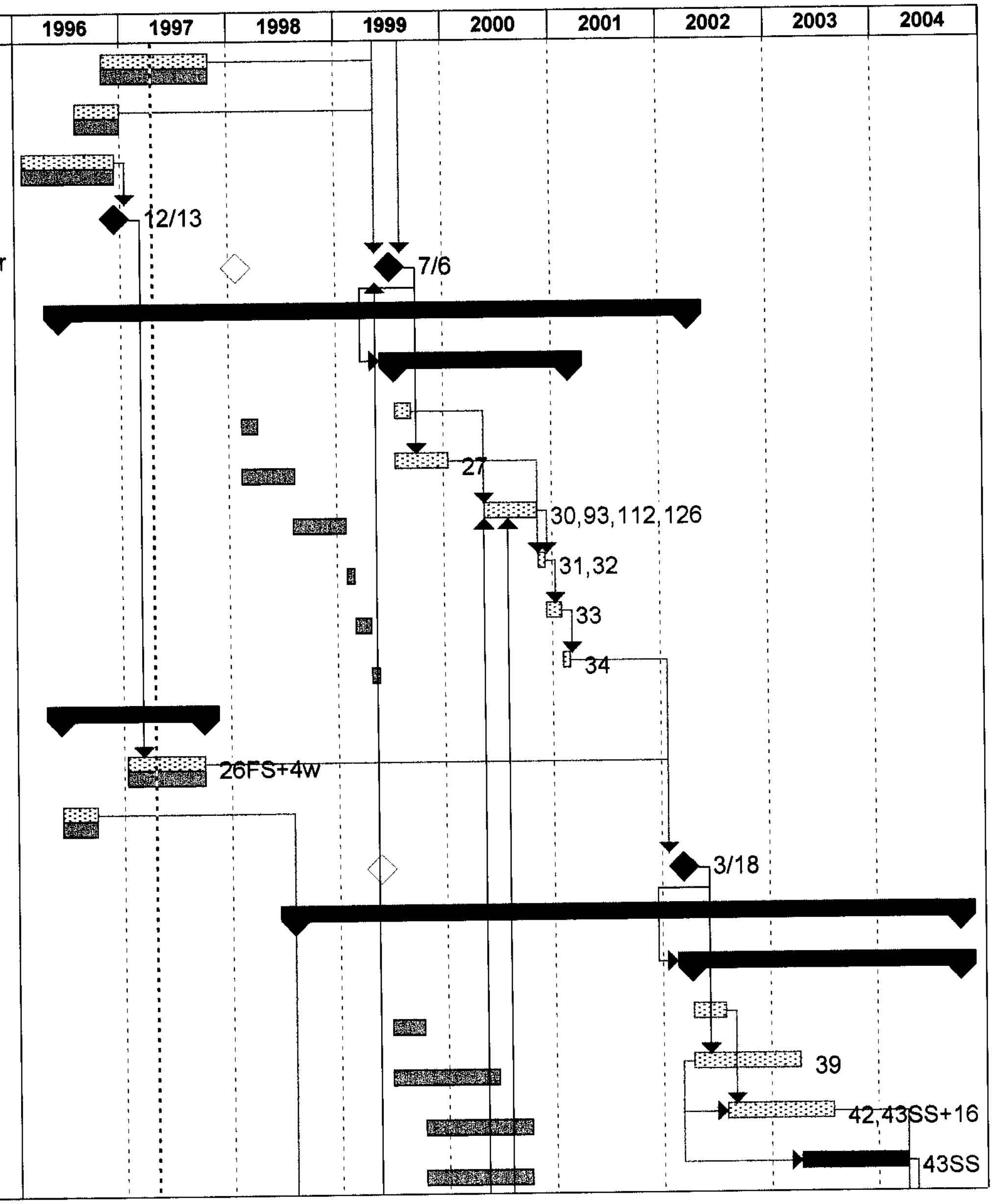
Ethanol Multi-Year Technical Plan
Critical Path Analysis for Resource Leveled Plan
Bioethanol Program Plan v24 level Near Term Critical Path

ID	Task Name
	Bioethanol Program Plan v24 level Near Term Critical Path
1	**Commercially demonstrate waste biomass to ethanol technology**
2	**Preliminary Feasibility Studies**
3	Conduct New Preliminary Feasibility Studies (supported by limited laboratory
4	**Complete Existing Preliminary Feasibility Studies (supported by limited laboratory **
5	**Near term softwood opportunities**
6	Quincy Library Group Feasibility Study (softwood)
7	Colorado "Pine Zone" Feasibility Study (softwood)
8	2 contracts (TBD)
9	PALCO and LP Feasibility Studies (softwood)
10	IBI CRADA (softwood)
11	CARB Bioethanol Life Cycle Analysis (softwood)
12	Washington State Energy Office Pulp Mill Feasibility Study (softwood)
13	ACE Feasibility Study (CRP grass)
14	Iowa Feasibility Study (CRP grass)
15	Delta-T CRADA (feedstock to be determined)
16	Cellulase Partnership with Iogen
17	Quaker Oats Chemicals/Manildra Feasibility Study (other feedstock)
18	Pure Vision Feasibility Study (other feedstock)
19	Select Partners for Final Feasibility Studies (apply Final Feasibility Study sele
20	**Final Feasibility Studies**
21	Conduct New Final Feasibility Studies (supported by laboratory work)
22	**Complete Existing Final Feasibility Studies (supported by laboratory work)**



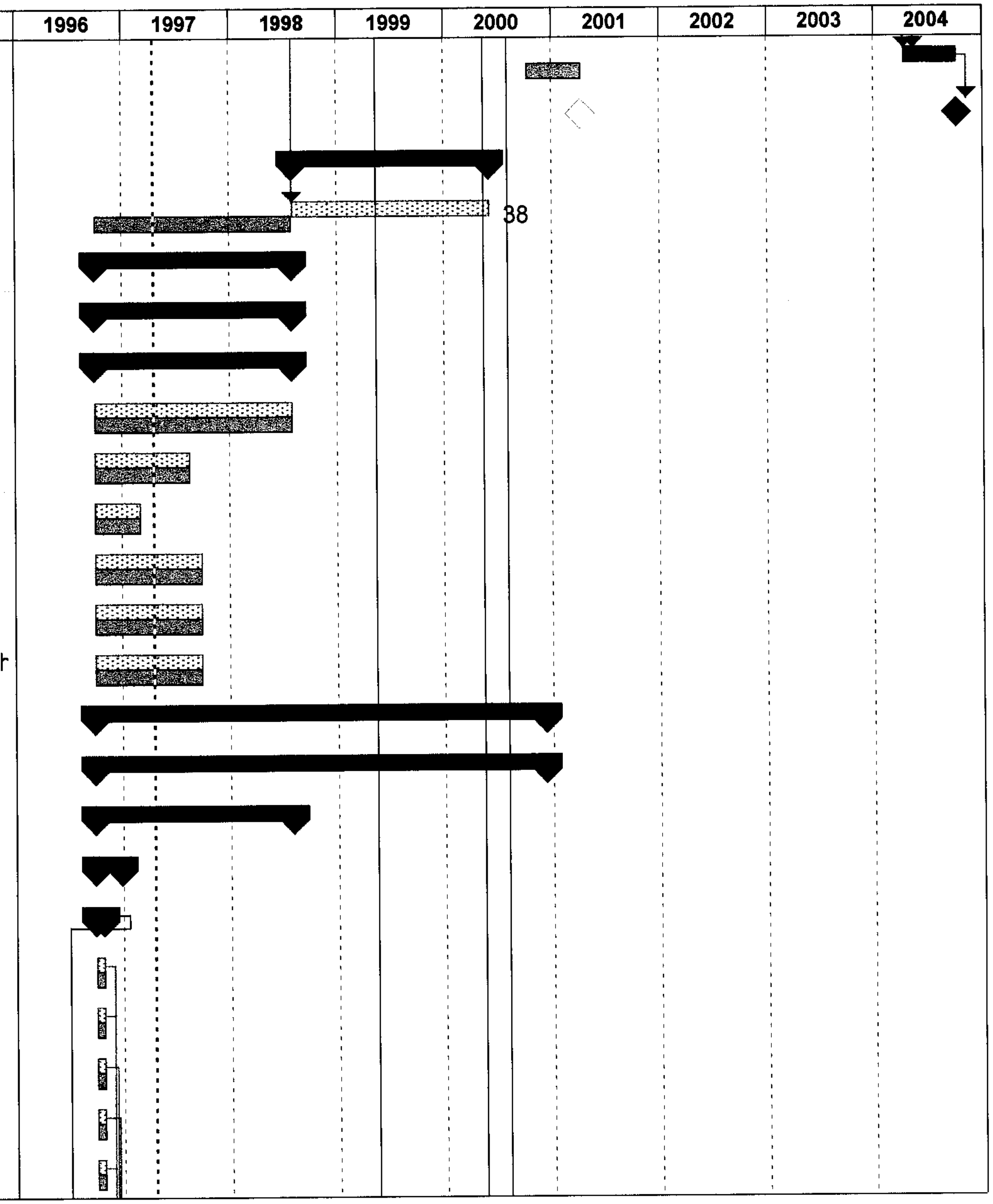
Ethanol Multi-Year Technical Plan
Critical Path Analysis for Resource Leveled Plan
Bioethanol Program Plan v24 level Near Term Critical Path

ID	Task Name
23	Coors CRADA Phase 2 (grain milling residue)
24	New Energy CRADA (grain milling residue)
25	Gridley Project Phase 1 (rice straw)
26	Gridley Phase 2 Go/No-go Decision
27	Select Partners for Business Plan Development (apply demonstration partner
28	**Business Plans**
29	**Conduct New Business Plans**
30	Negotiate Legal Arrangements with Partners
31	Establish Feedstock/Product Contracts and Site Commitments
32	Conduct PDU Testing and Data Analysis
33	Re-evaluate Process Design and Cost Estimate
34	Negotiate License Agreements and Performance Guarantees
35	Issue New Business Plans
36	**Complete Existing Business Plans**
37	Gridley Phase 2 - issue business plan
38	Amoco CRADA Phase 3
39	Select Partners for Demonstration Plant Development
40	**Demonstration Plants**
41	**Conduct New Demonstration Plant Efforts**
42	Finance Facility
43	Conduct Detailed Design
44	Obtain Permits
45	Construct Facility



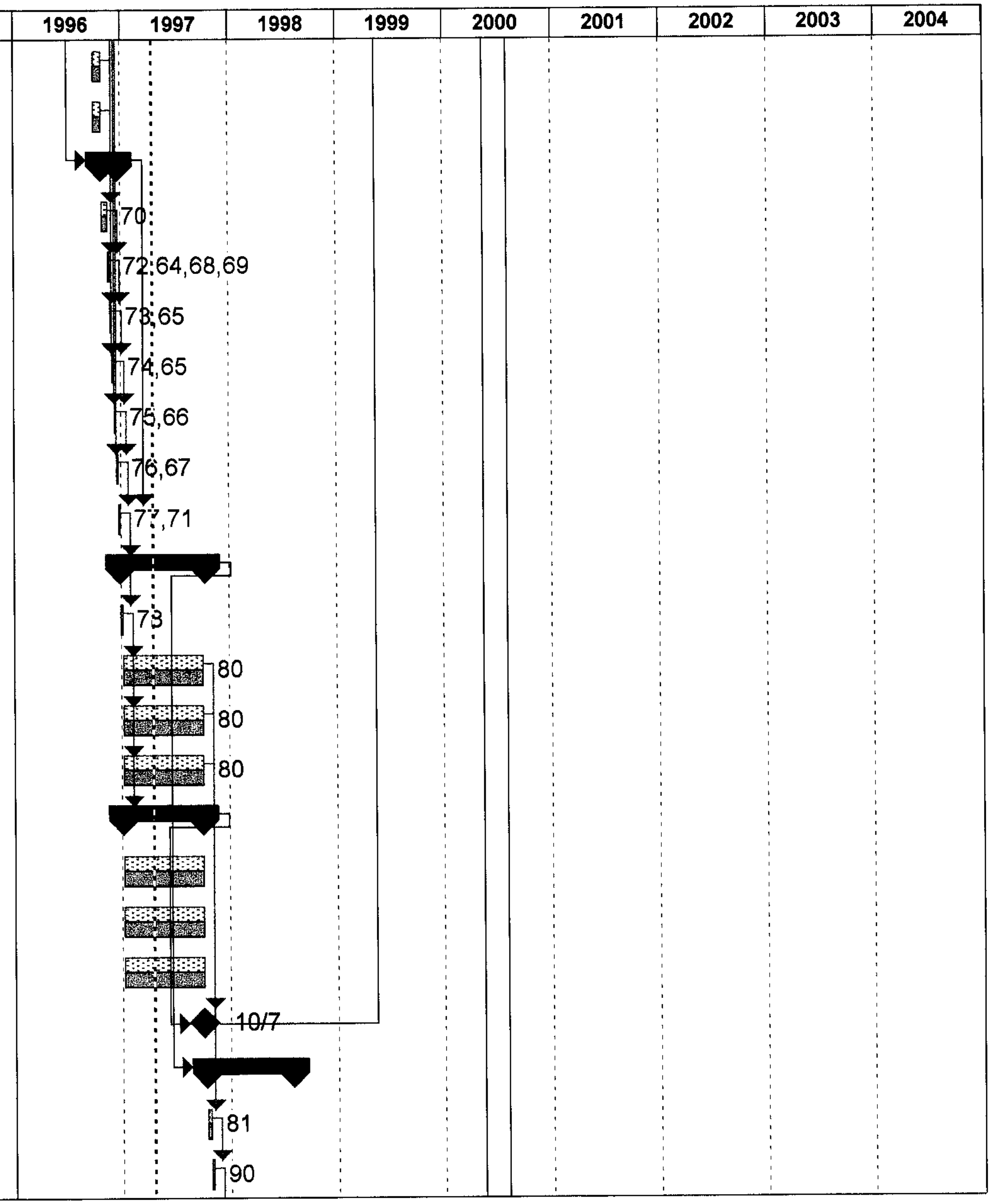
Ethanol Multi-Year Technical Plan
Critical Path Analysis for Resource Leveled Plan
Bioethanol Program Plan v24 level Near Term Critical Path

ID	Task Name
46	Start Up Facility by Year 2000
47	Commercial Operation
48	**Complete Existing Demonstration Plant Efforts**
49	Amoco CRADA Phase 4 - Final Report on Demonstration Plant Due
50	**Develop and Maintain PDT Capabilities and Data Bases to Support Year 2000 Goal**
51	**PDT Tools, Data Bases and Capabilities to Conduct Feasibility/Business Plans**
52	**Develop Data Base for Near-Term Feedstock**
53	Develop Forest Residue GIS Database
54	Develop Saw & Pulp Mill GIS Database
55	Montana State Wood Waste Assessment
56	Maintain PDT Engineering/Economic Analysis Models
57	Develop Data Base for Sources of Funding to Partners
58	Coordinate With Federal, State, Local & Private Organizations to Support Eth
59	**Core Technology Development**
60	**Biomass Conversion Technology**
61	**Softwood-specific process integration and process development activities**
62	**Preliminary Technology Analysis**
63	**Investigate technologies**
64	SO2 steam explosion
65	Dilute acid hydrolysis
66	Concentrated acid
67	ACOS Organosolv process
68	Enzyme production



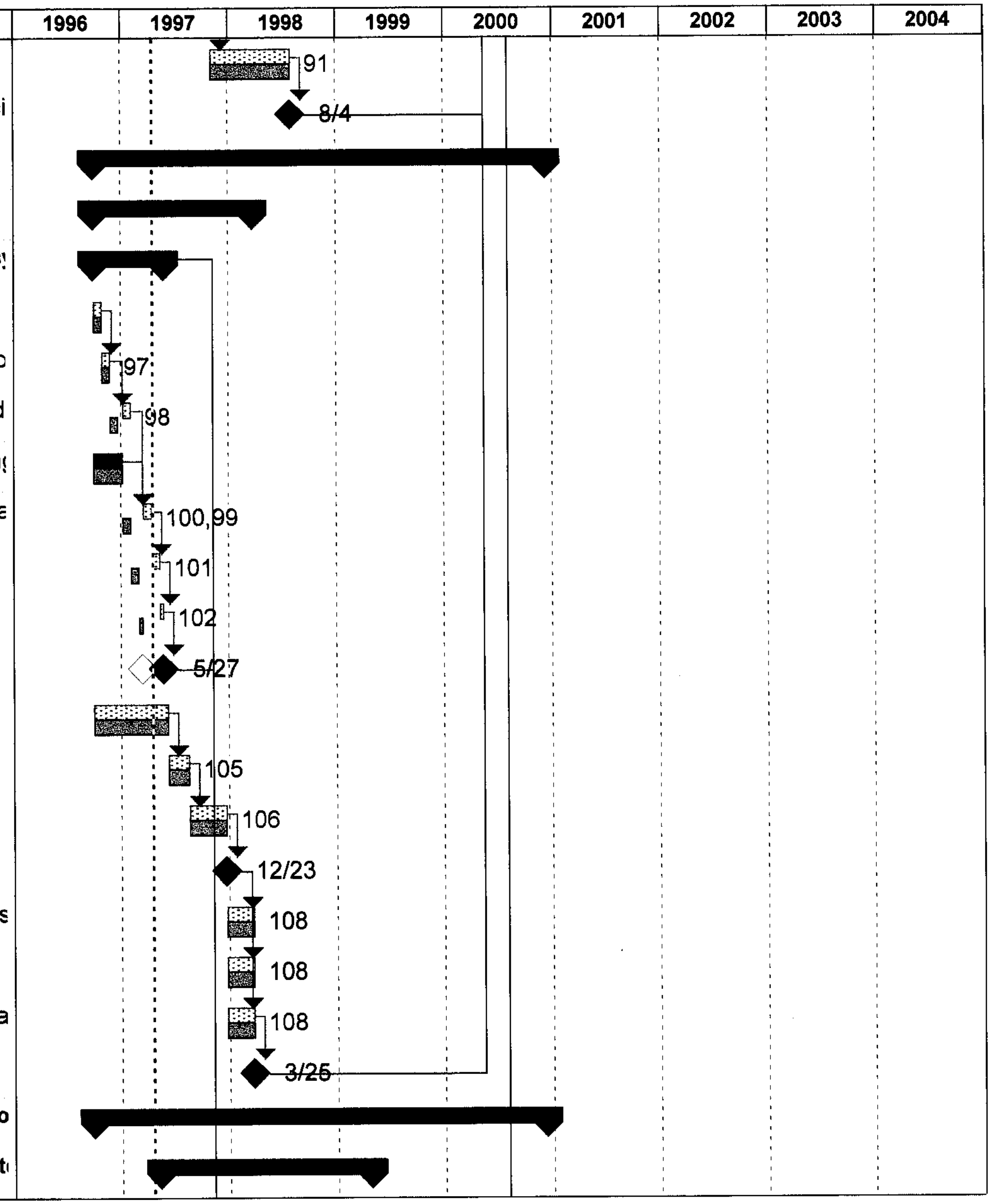
Ethanol Multi-Year Technical Plan
Critical Path Analysis for Resource Leveled Plan
Bioethanol Program Plan v24 level Near Term Critical Path

ID	Task Name
69	Fermentation/SHF/SSF
70	Lignin utilization
71	**Model 5 process options for softwoods**
72	Complete process & economic model
73	Option A
74	Option B
75	Option C
76	Option D
77	Option E
78	Identify technology gaps
79	**Fill Technology Gaps for Softwoods**
80	Revise softwoods technology plan
81	Subcontract or CRADA with UBC
82	Subcontract #2
83	Subcontract #3
84	**Pretreatment & fermentation work at NREL**
85	Dilute acid pretreatment
86	SO2 Steam explosion
87	C6 Fermentation R&D
88	Preliminary assessment of integrated technologies completed
89	**Process Selection and PDU Testing**
90	Revise Process Models
91	Select Process for further development



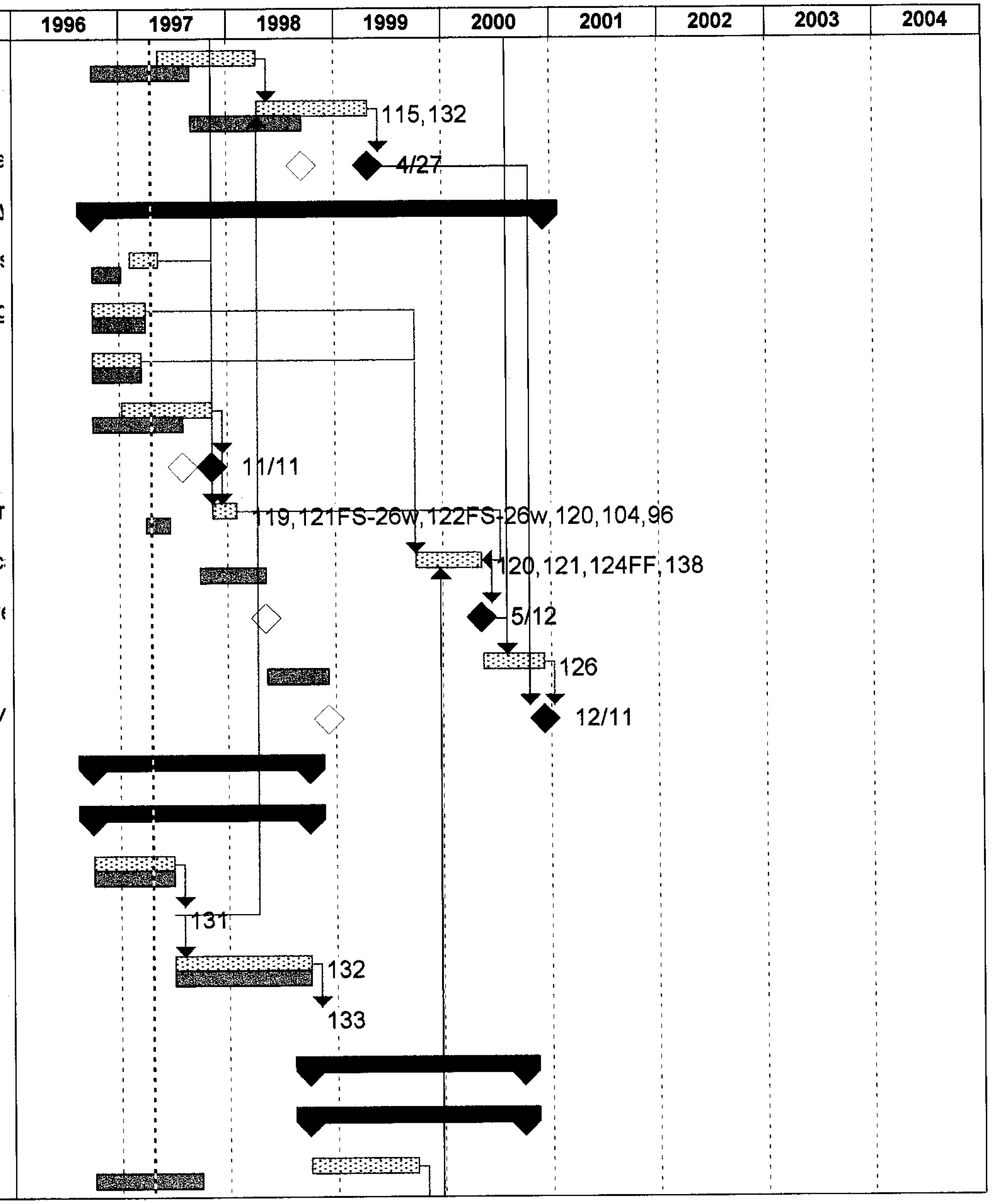
Ethanol Multi-Year Technical Plan
Critical Path Analysis for Resource Leveled Plan
Bioethanol Program Plan v24 level Near Term Critical Path

ID	Task Name	
92	Subcontract #4	91
93	Integrated process for softwood to ethanol technology available for commerci	8/4
94	**Process Integration and Process Development**	
95	**Provide commercial development facility capabilities to support industrial partners**	
96	**Demonstrate an integrated process for ethanol from cellulose in a mini-pilot plant s**	
97	Establish complete integrated process flow diagram for minipilot plant	
98	Prove that aseptic conditions can be maintained in the biochemical conversio	97
99	Obtain approval to operate the mini-pilot plant using a genetically engineered	98
100	Design, procure and test ion exchange equipment for hydrolysate conditionin	
101	Ready Sunds reactor to produce pretreated sawdust for integrated demonstra	100,99
102	Run process qualifier technology demonstration	101
103	Document process qualifier demonstration	102
104	Mini-pilot biochemical conversion unit available for commercial development	5/27
105	Design full pilot plant scale detoxification equipment	
106	Install full pilot plant scale detoxification equipment	105
107	Test and modify full pilot scale detoxification equipment	106
108	Detoxification process available for pilot scale commercial development	12/23
109	Design SSCF system for pilot plant demonstration based on experimental res	108
110	Evaluate spent solids for combustion value	108
111	Investigate the impacts of gypsum on the bioethanol process prior to pilot pla	108
112	Pilot scale testing capability available for use by commercial partners	3/25
113	**Provide integrated process technology for commercial development meeting the co**	
114	**Develop cellulase enzyme production technology utilizing hydrolysate and pretreat**	



Ethanol Multi-Year Technical Plan
Critical Path Analysis for Resource Leveled Plan
Bioethanol Program Plan v24 level Near Term Critical Path

ID	Task Name
115	Establish cellulase production on hydrolysate and pretreated solids
116	Improve cellulase production on hydrolysate and pretreated solids based on i
117	Cellulase enzyme production technology available for commercial developme
118	**Improve integrated process performance to achieve cost target for year 2000 deplo;**
119	Produce pretreated and detoxified materials to meet team experimental need:
120	Improve pretreatment to increase cellulose digestibility and hemicellulose su(
121	Develop Zymomonas strain adapted to 100 % hydrolysate
122	Complete detoxification process development at the bench scale
123	Provide data on applicability of detoxification to various feedstocks
124	Investigate SSCF performance by consideration of alternate process configur
125	Investigate SSCF performance utilizing improved pretreatment, best detoxific
126	Improved process technology ready for review and generation of new improv(
127	Prioritized improvement projects carried out
128	Integrated biomass to ethanol technology meeting year 2000 performance av
129	**Enzyme Technology R&D**
130	**Near Term Enzyme R&D**
131	T. reesei: Decrease cellulase cost by optimizing induction protocols
132	Deliver new protocols to EPD
133	T. reesei: Determine effects of induction protocols on component enzymes
134	Report correlation between T. reesei induction and enzyme mix
135	**Fermentation Organism Development**
136	**Develop Zymomonas Organism for use in year 2000 waste to ethanol facility**
137	Evaluate new new Zymomonas strains



Ethanol Multi-Year Technical Plan
Critical Path Analysis for Resource Leveled Plan
Bioethanol Program Plan v24 level Near Term Critical Path

ID	Task Name	1996	1997	1998	1999	2000	2001	2002	2003	2004
138	Select strains for hand-off to integration studies					9/30				
139	Develop further improvements to Zymomonas organism						137			
140	Hand-off improved Zymomonas strain for pilot scale demonstration work with						139			

Figure 25: Ethanol Multi-Year Technical Plan: Critical Path Analysis for Near Term Deployment in Resource-Leveled Plan

Shown on next 6 pages

11. Critical Path Analysis of Mid Term Technology Deployment Goal

As with the near term goal, it was necessary to go through the plan and eliminate all activities that do not support goals occurring before the deployment target date. Likewise, we have done this analysis for both the baseline plan and the resource-loaded plan.

11.1 The Baseline Plan

Critical activities include the following:

- PDU testing of integrated technology
- Negotiation and final business plan development
- All demonstration activities supporting both the agricultural production and the feedstock conversion technology
- Roll-out of second technology improvements for near term technology
- Integration of technology for conversion of switchgrass
- Within applied research, the entire set of activities required to develop countercurrent prehydrolysis technology are in the critical path
- Also, a variety of activities within enzyme, fermentation organism, and lignin technology development are critical

It makes sense that, for the mid term technology, we would see more critical tasks within the core technology areas.

11.2 Resource-Leveled Plan

The main critical path remaining in the plan after leveling of resources starts with the PDU scale testing of the switchgrass conversion technology and continues through demonstration steps for the agricultural production and conversion technology.

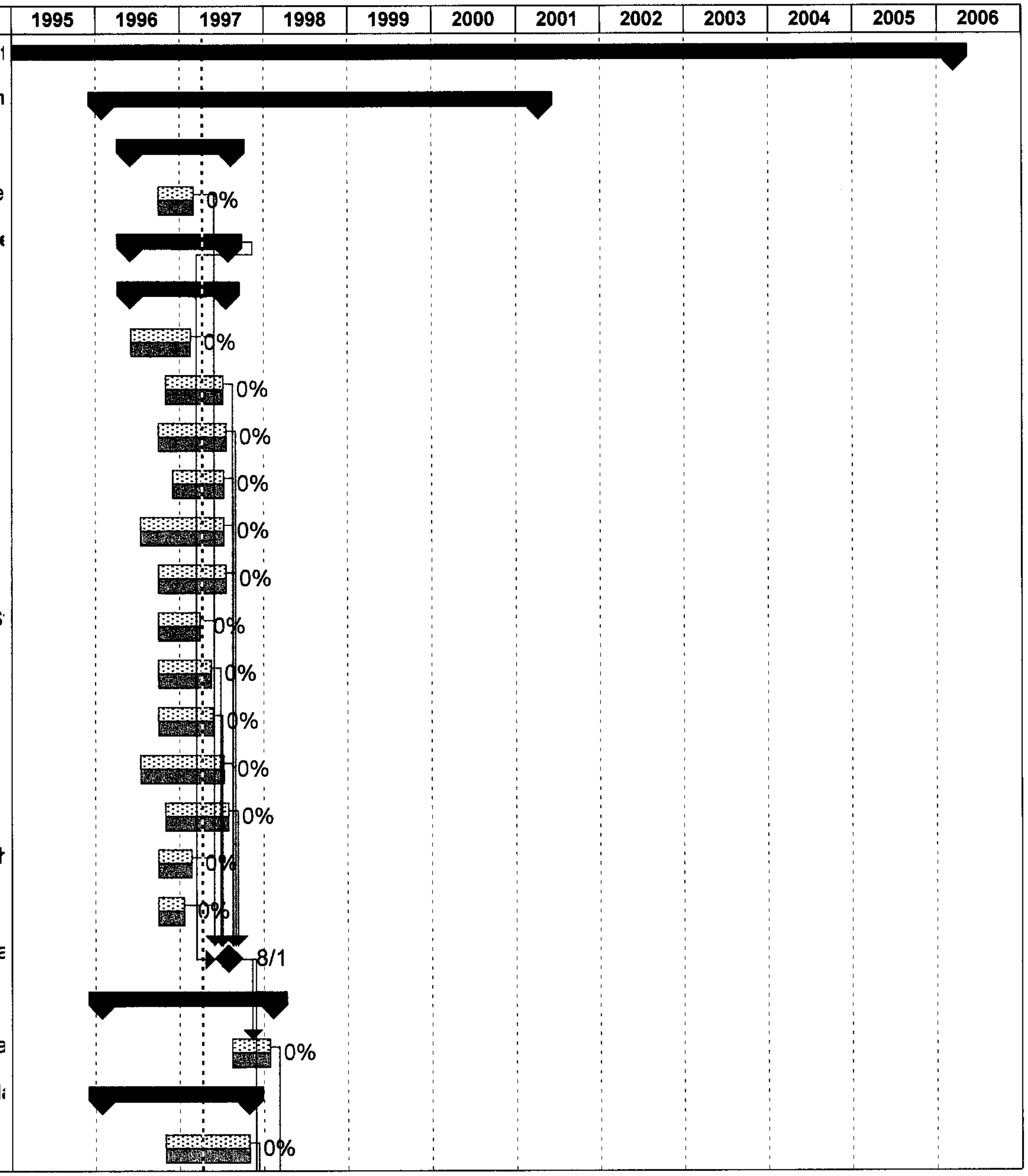
Beyond this section of the plan, process integration and some aspects of the fermentation organism development effort that affect the critical path

Figure 26: Ethanol Multi-Year Technical Plan: Critical Path Analyses for Mid Term Deployment Goal in Baseline Plan

Shown on next 18 pages

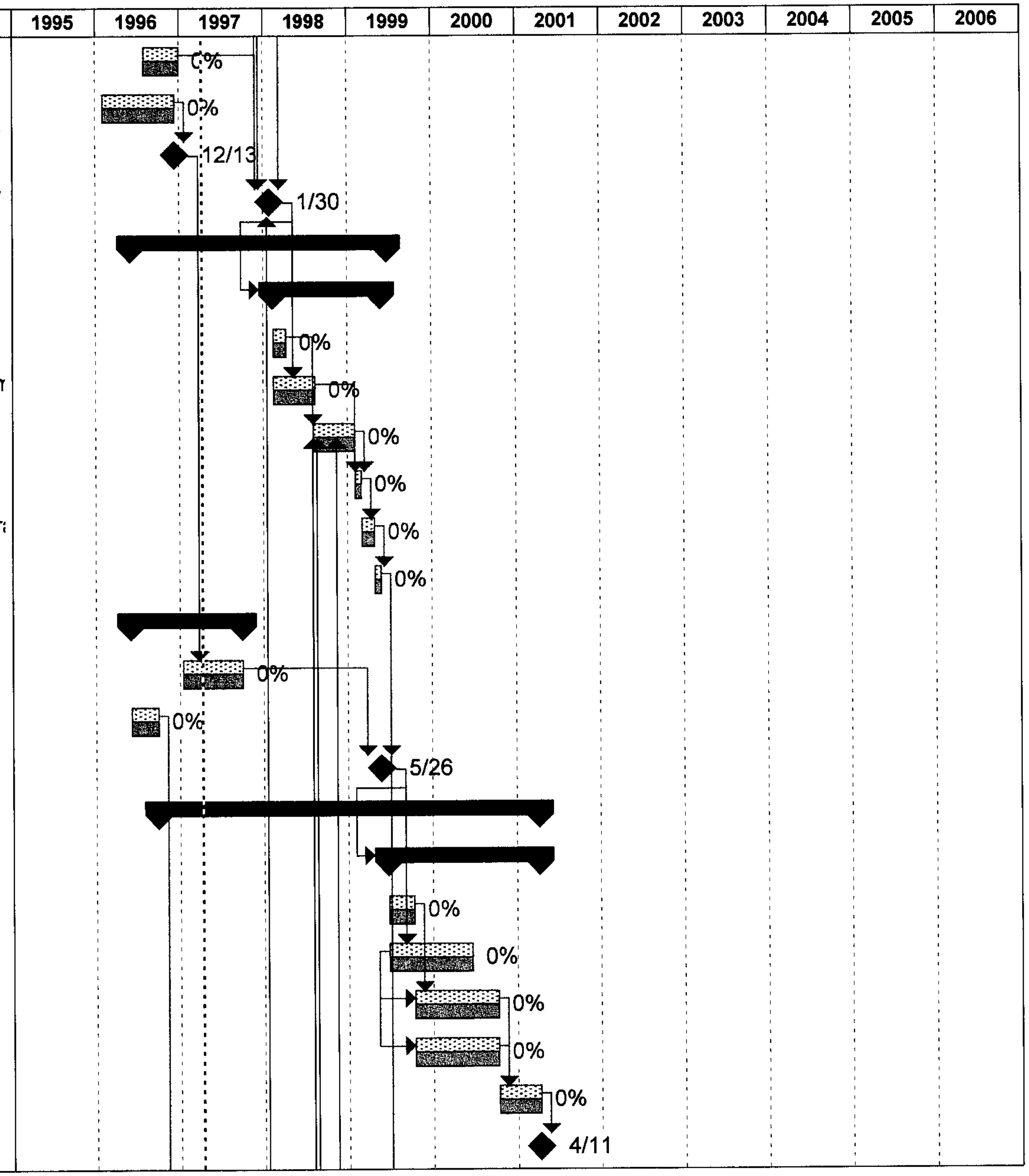
Critical Path Analysis for Switchgrass Technology Baseline Plan
Bioethanol Program Plan v24 Switchgrass Critical Path

ID	WBS	Task Name
	0	**Bioethanol Program Plan v24 Switchgrass Crit**
1	1	**Commercially demonstrate waste biomass to ethanol techn**
2	1.1	**Preliminary Feasibility Studies**
3	1.1.1	Conduct New Preliminary Feasibility Studies (supporte
4	1.1.2	**Complete Existing Preliminary Feasibility Studies (support**
5	1.1.2.1	**Near term softwood opportunities**
6	1.1.2.1.1	Quincy Library Group Feasibility Study (softwood)
7	1.1.2.1.2	Colorado "Pine Zone" Feasibility Study (softwood)
8	1.1.2.1.3	2 contracts (TBD)
9	1.1.2.1.4	PALCO and LP Feasibility Studies (softwood)
10	1.1.2.1.5	IBI CRADA (softwood)
11	1.1.2.1.6	CARB Bioethanol Life Cycle Analysis (softwood)
12	1.1.2.1.7	Washington State Energy Office Pulp Mill Feasibility S
13	1.1.2.2	ACE Feasibility Study (CRP grass)
14	1.1.2.3	Iowa Feasibility Study (CRP grass)
15	1.1.2.4	Delta-T CRADA (feedstock to be determined)
16	1.1.2.5	Cellulase Partnership with Iogen
17	1.1.2.6	Quaker Oats Chemicals/Manildra Feasibility Study (oth
18	1.1.2.7	Pure Vision Feasibility Study (other feedstock)
19	1.1.3	Select Partners for Final Feasibility Studies (apply Fina
20	1.2	**Final Feasibility Studies**
21	1.2.1	Conduct New Final Feasibility Studies (supported by la
22	1.2.2	**Complete Existing Final Feasibility Studies (supported by l**
23	1.2.2.1	Coors CRADA Phase 2 (grain milling residue)



Critical Path Analysis for Switchgrass Technology Baseline Plan
Bioethanol Program Plan v24 Switchgrass Critical Path

ID	WBS	Task Name
24	1.2.2.2	New Energy CRADA (grain milling residue)
25	1.2.2.3	Gridley Project Phase 1 (rice straw)
26	1.2.2.4	Gridley Phase 2 Go/No-go Decision
27	1.2.3	Select Partners for Business Plan Development (apply
28	**1.3**	**Business Plans**
29	**1.3.1**	**Conduct New Business Plans**
30	1.3.1.1	Negotiate Legal Arrangements with Partners
31	1.3.1.2	Establish Feedstock/Product Contracts and Site Comm
32	1.3.1.3	Conduct PDU Testing and Data Analysis
33	1.3.1.4	Re-evaluate Process Design and Cost Estimate
34	1.3.1.5	Negotiate License Agreements and Performance Guar
35	1.3.1.6	Issue New Business Plans
36	**1.3.2**	**Complete Existing Business Plans**
37	1.3.2.1	Gridley Phase 2 - issue business plan
38	1.3.2.2	Amoco CRADA Phase 3
39	1.3.3	Select Partners for Demonstration Plant Development
40	**1.4**	**Demonstration Plants**
41	**1.4.1**	**Conduct New Demonstration Plant Efforts**
42	1.4.1.1	Finance Facility
43	1.4.1.2	Conduct Detailed Design
44	1.4.1.3	Obtain Permits
45	1.4.1.4	Construct Facility
46	1.4.1.5	Start Up Facility by Year 2000
47	1.4.1.6	Commercial Operation



Critical Path Analysis for Switchgrass Technology Baseline Plan
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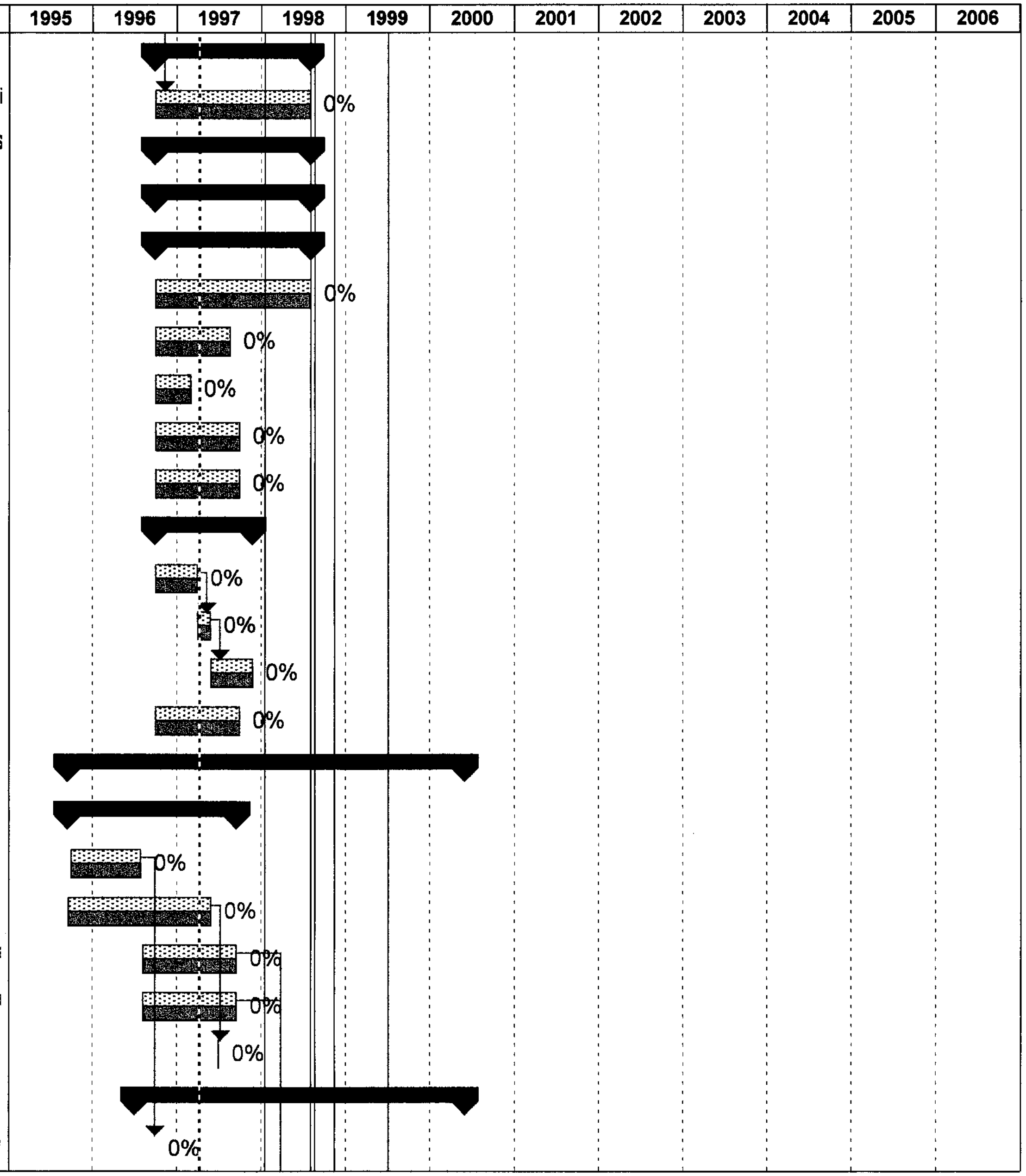
ID	WBS	Task Name
48	**1.4.2**	**Complete Existing Demonstration Plant Efforts**
49	1.4.2.1	Amoco CRADA Phase 4 - Final Report on Demonstrati
50	**2**	**Develop and Maintain PDT Capabilities and Data Bases to S**
51	**2.1**	**PDT Tools, Data Bases and Capabilities to Conduct Feasibi**
52	**2.1.1**	**Develop Data Base for Near-Term Feedstock**
53	2.1.1.1	Develop Forest Residue GIS Database
54	2.1.1.2	Develop Saw & Pulp Mill GIS Database
55	2.1.1.3	Montana State Wood Waste Assessment
56	2.1.2	Maintain PDT Engineering/Economic Analysis Models
57	2.2	Develop Data Base for Sources of Funding to Partners
58	**3**	**Establish Partnerships for Long-Term Research**
59	3.1	Determine Key Long-Term Research Objectives
60	3.2	Determine Who Should Conduct Research to Achieve
61	3.3	Establish Partnerships with Non-NREL Entities
62	4	Coordinate With Federal, State, Local & Private Organ
63	**5**	**Develop Switchgrass Partnerships for Ethanol Production**
64	**5.1**	**Identify potential locations for crop supplies at $42/dry ton**
65	5.1.1	Complete crop economic baselines at national and reg
66	5.1.2	Complete integrated GIS analysis in selected states (4
67	5.1.3	Complete Integrated GIS analysis of potential in 14 st:
68	5.1.4	Complete preliminary waste and feedstock supply data
69	5.1.5	Recommend locations for focused R&D, scale-up and
70	**5.2**	**Assist feasibility studies with integrated analysis products**
71	5.2.1	Provide integrated crop economic models for develope



Critical Path Analysis for Switchgrass Technology Baseline Plan
Bioethanol Program Plan v24 Switchgrass Critical Path

ID	WBS	Task Name	1995–2006
72	5.2.2	Provide results of GIS model runs to states, developer:	0%
73	5.2.3	Provide feedstock supply curves for ethanol market pe	0%
74	5.2.4	Collaborate with USDA on putting switchgrass & SRW	0%
75	5.2.5	Use USDA models for improving feedstock supply cur\	0%
76	5.2.6	Integrate cost & production risks in farmer decision ma	0%
77	5.2.7	Publish crop supply models and scenario results (4.01	0%
78	5.2.8	Recommend locations for preliminary feasibility studie:	0%
79	5.2.9	Update crop economic info as new data becomes avail	0%
80	5.2.10	Release updated crop economic models for developers	0%
81	**5.3**	**Expand switchgrass supply system expertise & interest**	
82	5.3.1	Summarize and publish results of first 5 yrs SG R&D	0%
83	**5.3.2**	**Expand number and scale of switchgrass testing locations**	
84	5.3.2.1	Farmer participation in Chariton Valley, Iowa secured	0%
85	5.3.2.2	Renegotiate Univ. contracts to include scale-ups & sat	0%
86	5.3.2.3	Negotiate extending variety testing & breeding to Wisc	0%
87	5.3.2.4	USDA Plant Materials Center Participation Secured	0%
88	**5.3.3**	**Predict switchgrass market potential for feasibility studies**	
89	5.3.3.1	Link ISU economics experts with Chariton RC&D (5.05	0%
90	5.3.3.2	Link ag economics expertise with other scale-up sites (	0%
91	5.3.3.3	Provide economic info for final feasibility studies	0%
92	**5.3.4**	**Predict environmental effects of switchgrass supply systen**	
93	5.3.4.1	Develop models for national/regional environmental eff	0%
94	5.3.4.2	Model & predict regional level water quality effects (4.0	0%
95	5.3.4.3	Collect & evaluate info on soil nutrient and carbon char	0%

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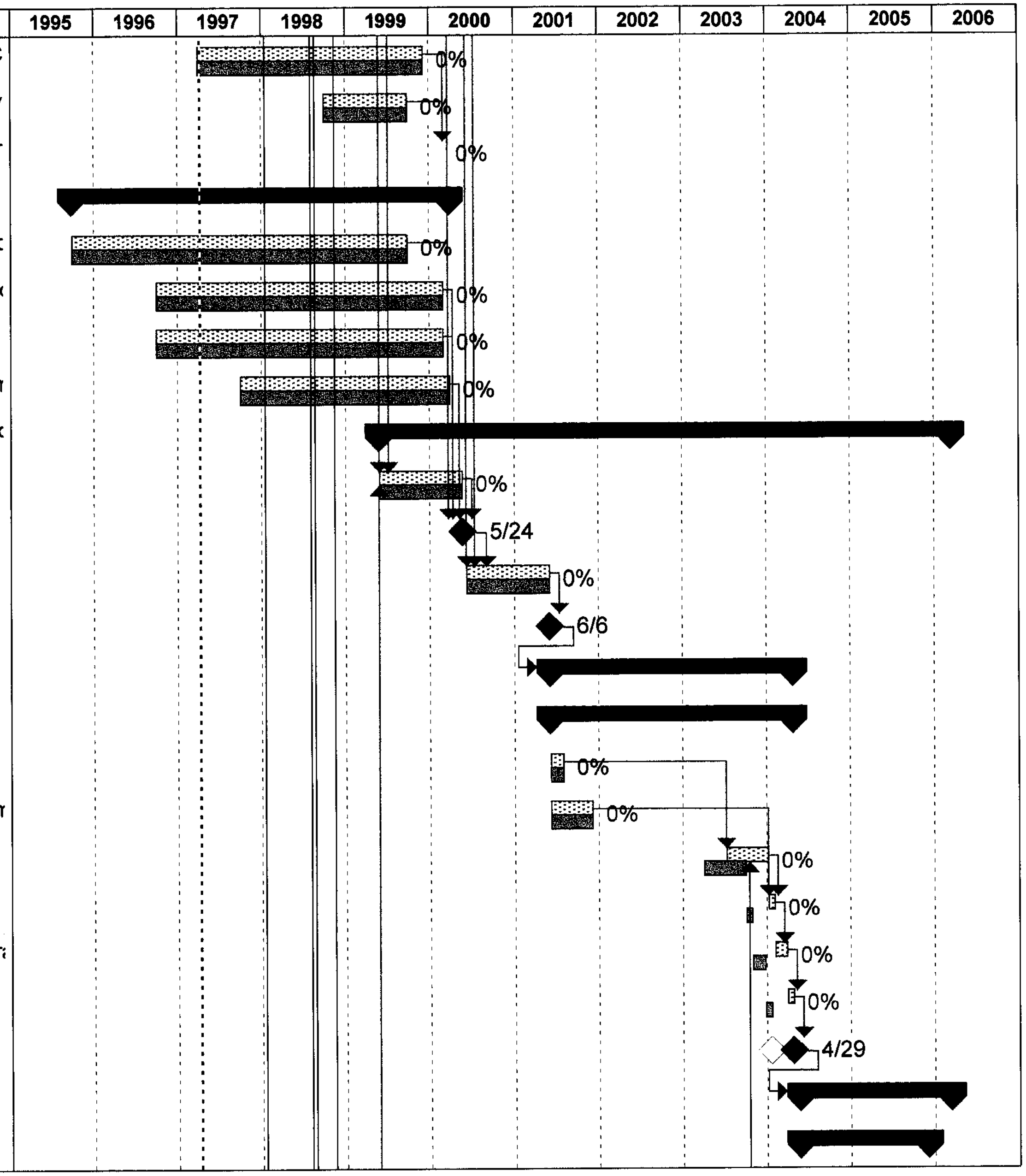
ID	WBS	Task Name
96	5.3.4.4	Model erosion and water quality effects in Iowa (CVRC
97	5.3.4.5	Compare SG & alt. crop environmental effects from av
98	5.3.4.6	Publish preliminary predictions of env. effects of switch
99	**5.3.5**	**Stimulate producer interest in business plan development**
100	5.3.5.1	Develop farmer oriented news outlets, hold news broac
101	5.3.5.2	Conduct field days and workshops for farmers & devel
102	5.3.5.3	Develop networks with farmers and developers (5.0)
103	5.3.5.4	Educate public, developers, policy makers on environn
104	**6**	**Commercially demonstrate switchgrass to ethanol technolc**
105	6.1	Preliminary feasibility studies
106	6.2	Select partners for final feasibility studies
107	6.3	Final feasibility studies
108	6.4	Select partners for business plan development
109	**6.5**	**Business Plans**
110	**6.5.1**	**Conduct New Business Plans**
111	6.5.1.1	Negotiate Legal Arrangements with Partners
112	6.5.1.2	Establish Feedstock/Product Contracts and Site Comm
113	6.5.1.3	Conduct PDU Testing and Data Analysis
114	6.5.1.4	Re-evaluate Process Design and Cost Estimate
115	6.5.1.5	Negotiate License Agreements and Performance Guar
116	6.5.1.6	Issue New Business Plans
117	6.6	Select Partners for Demonstration Plant Development
118	**6.7**	**Demonstration Plants**
119	**6.7.1**	**Agricultural Production**



Critical Path Analysis for Switchgrass Technology Baseline Plan
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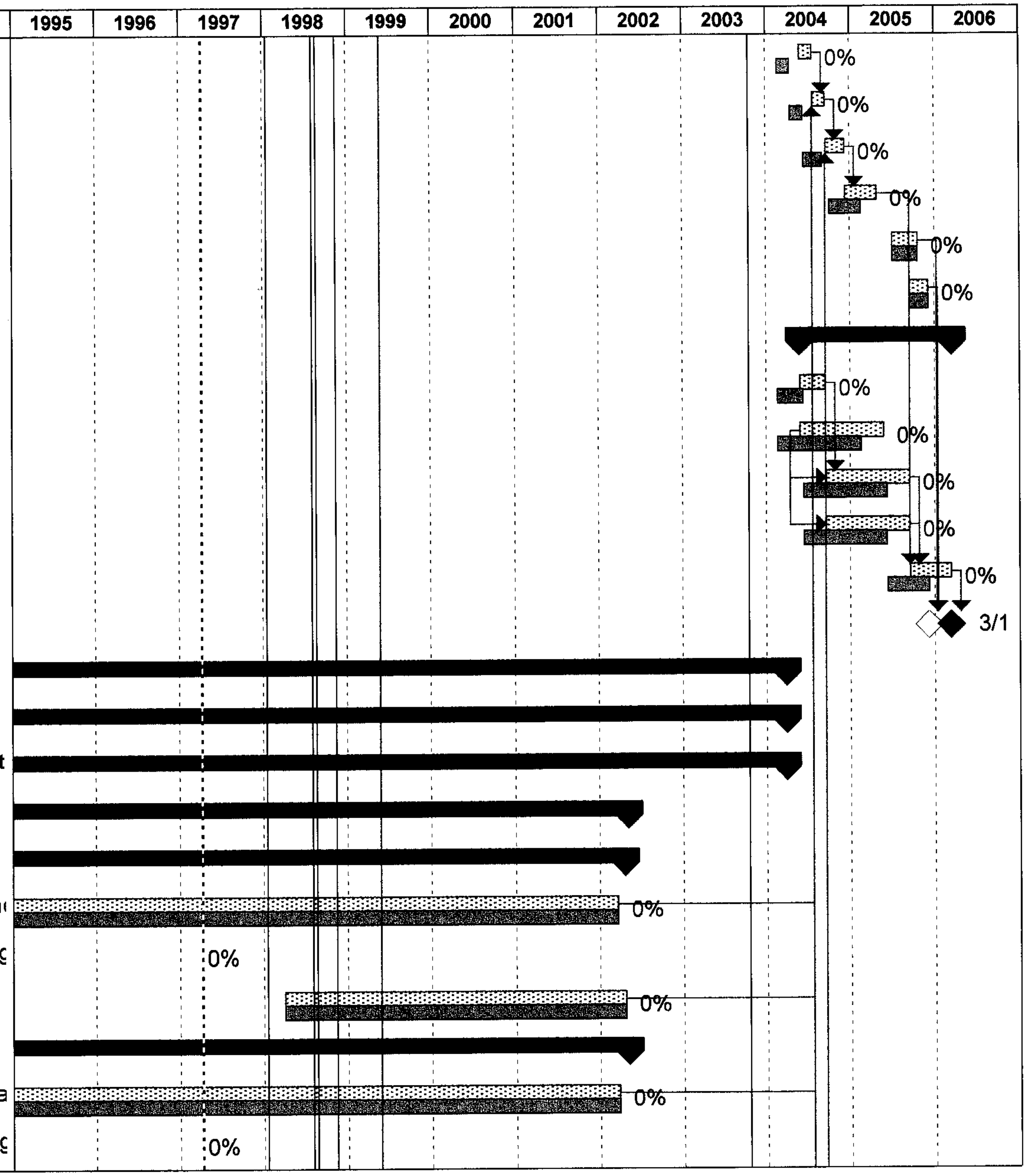
ID	WBS	Task Name
120	6.7.1.1	Establish Feedstock Supply Contracts & Financing
121	6.7.1.2	Fall site preparation & secure seed
122	6.7.1.3	Spring site preparation & planting
123	6.7.1.4	First year harvest (stored for start-up runs)
124	6.7.1.5	Evaluate supply & contract for wastes if necessary
125	6.7.1.6	Second year harvest;pre-commercial start-up
126	**6.7.2**	**Conduct New Demonstration Plant Efforts**
127	6.7.2.1	Finance Facility
128	6.7.2.2	Conduct Detailed Design
129	6.7.2.3	Obtain Permits
130	6.7.2.4	Construct Facility
131	6.7.2.5	Start Up Facility by Year 2005
132	6.7.2.6	Commercial Operation
133	**7**	**Core Technology Development**
134	**7.1**	**Switchgrass Feedstock Production Technology**
135	**7.1.1**	**Support Switchgrass Crop Development Centers in at least**
136	**7.1.1.1**	**Identify best varieties and yield potential**
137	**7.1.1.1.1**	**Screen for best varieties in South & Mid-Atlantic States**
138	7.1.1.1.1.1	Screen available varieties at 19 sites for high& sustain
139	7.1.1.1.1.2	Recommend best varieties for first scale-up & breeding
140	7.1.1.1.1.3	Expand variety screening to 13 other states
141	**7.1.1.1.2**	**Screen for best varieties & locations in NC & NE/L states**
142	7.1.1.1.2.1	Screen available varieties in Nebraska for high & susta
143	7.1.1.1.2.2	Recommend best varieties for first scale-up & breeding



Critical Path Analysis for Switchgrass Technology Baseline Plan
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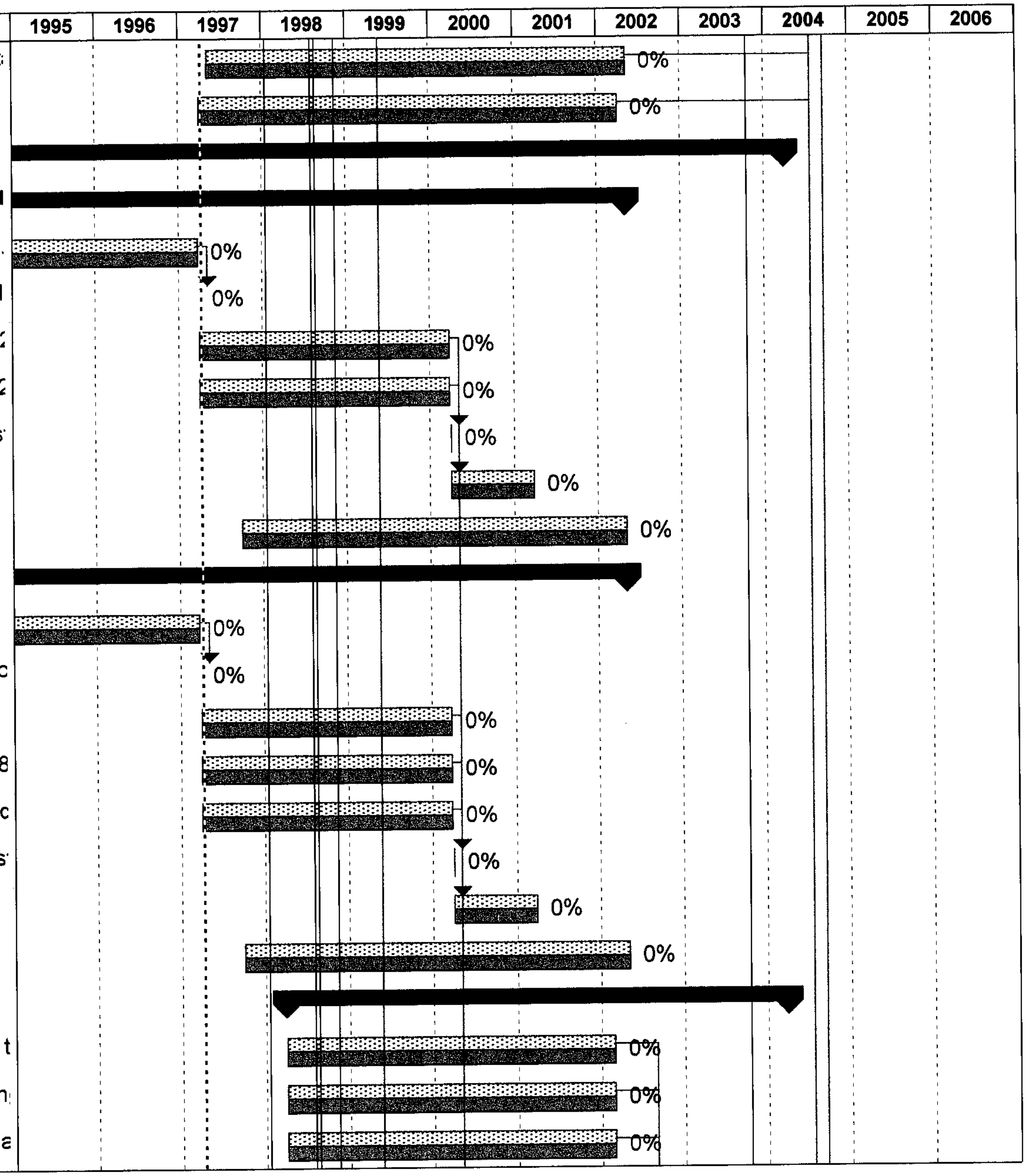
ID	WBS	Task Name
144	7.1.1.1.2.3	Screen available varieties in Wisconsin for high & sust
145	7.1.1.1.2.4	Expand variety screening to 10 other states
146	**7.1.1.2**	**Optimize culture to improve yields & benefit environment**
147	**7.1.1.2.1**	**Test culture effects in Southern & Mid-Atl. experiments 1-1**
148	7.1.1.2.1.1	Identify establishment & fertilizer requirements (2.02,2.
149	7.1.1.2.1.2	Provide preliminary crop mgm guidelines for R&D scal
150	7.1.1.2.1.3	Identify nutrient factors affecting yield & quality (2.02, 2
151	7.1.1.2.1.4	Identify harvest factors affecting yield & quality (2.02, 2
152	7.1.1.2.1.5	Provide improved crop mgm guidelines for feasibility s
153	7.1.1.2.1.6	Use data to improve econ., env, and supply models
154	7.1.1.2.1.7	Repeat above in 13 other states with extension links
155	**7.1.1.2.2**	**Test culture effects in NC experiments 1-10 acre**
156	7.1.1.2.2.1	Identify establishment & fertilizer requirements (2.07)
157	7.1.1.2.2.2	Provide preliminary crop mgm guidelines to growers fc
158	7.1.1.2.2.3	Identify nutrient factors affecting yield & quality (2.08)
159	7.1.1.2.2.4	Identify harvest factors affecting yield and quality (2.08
160	7.1.1.2.2.5	Develop information necessary to register new herbicic
161	7.1.1.2.2.6	Provide improved crop mgm guidelines for feasibility s
162	7.1.1.2.2.7	Use data to improve econ., env., and supply models
163	7.1.1.2.2.8	Repeat above in 13 other states with extension links
164	**7.1.1.2.3**	**Improve culture through understanding mechanisms**
165	7.1.1.2.3.1	Develop mechanistic understanding of yield response t
166	7.1.1.2.3.2	Develop mechanistic understanding of responses to m
167	7.1.1.2.3.3	Develop information on value of ash & wastes as soil a



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ID	WBS	Task Name
168	7.1.1.2.3.4	Use information to improve culture guidelines
169	7.1.1.2.3.5	Use information to improve national feedstock supply r
170	**7.1.1.2.4**	**Adapt culture to potential locations for commercial demos**
171	7.1.1.2.4.1	Identify best establishment techniques for locations
172	7.1.1.2.4.2	Test range of fertilizer levels & methods of appl.
173	7.1.1.2.4.3	Test herbicide types, rates, & appl. methods
174	**7.1.1.3**	**Evaluate environmental effects of culture techniques at few**
175	**7.1.1.3.1**	**Develop SE management options for environmentally soun**
176	7.1.1.3.1.1	Evaluate surface & subsurface water quality as functioi
177	7.1.1.3.1.2	Evaluate soil quality responses as function of managei
178	7.1.1.3.1.3	Provide site mgm/env guidelines to growers & EPA
179	**7.1.1.3.2**	**Develop NC site management options for environmental so**
180	7.1.1.3.2.1	Evaluate subsurface water quality as function of mana
181	7.1.1.3.2.2	Evaluate soil quality responses as function of managei
182	7.1.1.3.2.3	Provide site mgm/env. guidelines to growers & EPA
183	7.1.1.3.3	Educate multiple groups on environmental benefits
184	7.1.1.3.4	Integrate culture research results into analysis & guide
185	**7.1.1.4**	**Develop physiology/biotechnology information**
186	7.1.1.4.1	Improve growth physiology understanding and links to
187	7.1.1.4.2	Develop enhanced breeding techniques based on tissu
188	7.1.1.4.3	Handoff information to breeding activities/private secto
189	**7.1.1.5**	**Assure sustainable yields by addressing pathogen & pest i**
190	7.1.1.5.1	Use Iowa scale-up to monitor pathogens and pests
191	7.1.1.5.2	Monitor pathogens &pests in all additional scale-ups

Critical Path Analysis for Switchgrass Technology Baseline Plan
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ID	WBS	Task Name	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
192	7.1.1.5.3	Evaluate control mechanisms for pathogens and pests										0%		
193	7.1.1.5.4	Include pathogen/pest resistance in breeding efforts										0%		
194	**7.1.2**	**Reduce risks & expand expertise through scale-up researcl**												
195	**7.1.2.1**	**Expand number and scale of switchgrass field R&D project**												
196	7.1.2.1.1	New plantings in Chariton Valley, Iowa (4000 acres)										0%		
197	7.1.2.1.2	New plantings in SC region (20-50 acres) (2.03)										0%		
198	7.1.2.1.3	New plantings in SE region (20-500 acres), (2.04)										0%		
199	7.1.2.1.4	New plantings in alternate region (20-50 acres)										0%		
200	**7.1.2.2**	**Improve Engineering of Switchgrass Harvest, Handling & S**												
201	7.1.2.2.1	Test/modify existing large harvesters to handle higher							0%					
202	7.1.2.2.2	Test/modify existing small harvesters to handle higher							0%					
203	7.1.2.2.3	Identify best field storage & handling alternatives for N							0%					
204	7.1.2.2.4	Identify best field storage & handling alternatives for SI							0%					
205	7.1.2.2.5	Identify transportation & size reduction options							0%					
206	7.1.2.2.6	Provide information to assist partnership arrangements							0%					
207	**7.1.2.3**	**Perform economic and risk studies with scale-up data**												
208	7.1.2.3.1	Evaluate yield and production cost variation data								0%				
209	7.1.2.3.2	Evaluate storage, handling, transportation cost variatic								0%				
210	7.1.2.3.3	Evaluate financing and procurement strategies								0%				
211	7.1.2.3.4	Provide information to update business plans								0%				
212	**7.1.2.4**	**Monitor and document environmental effects**												
213	7.1.2.4.1	Monitor soil quality changes across Iowa Scaleup									0%			
214	7.1.2.4.2	Document biodiversity and wildlife habitat effects in lov									0%			
215	7.1.2.4.3	Continue evaluating erosion & water quality effects in I									0%			

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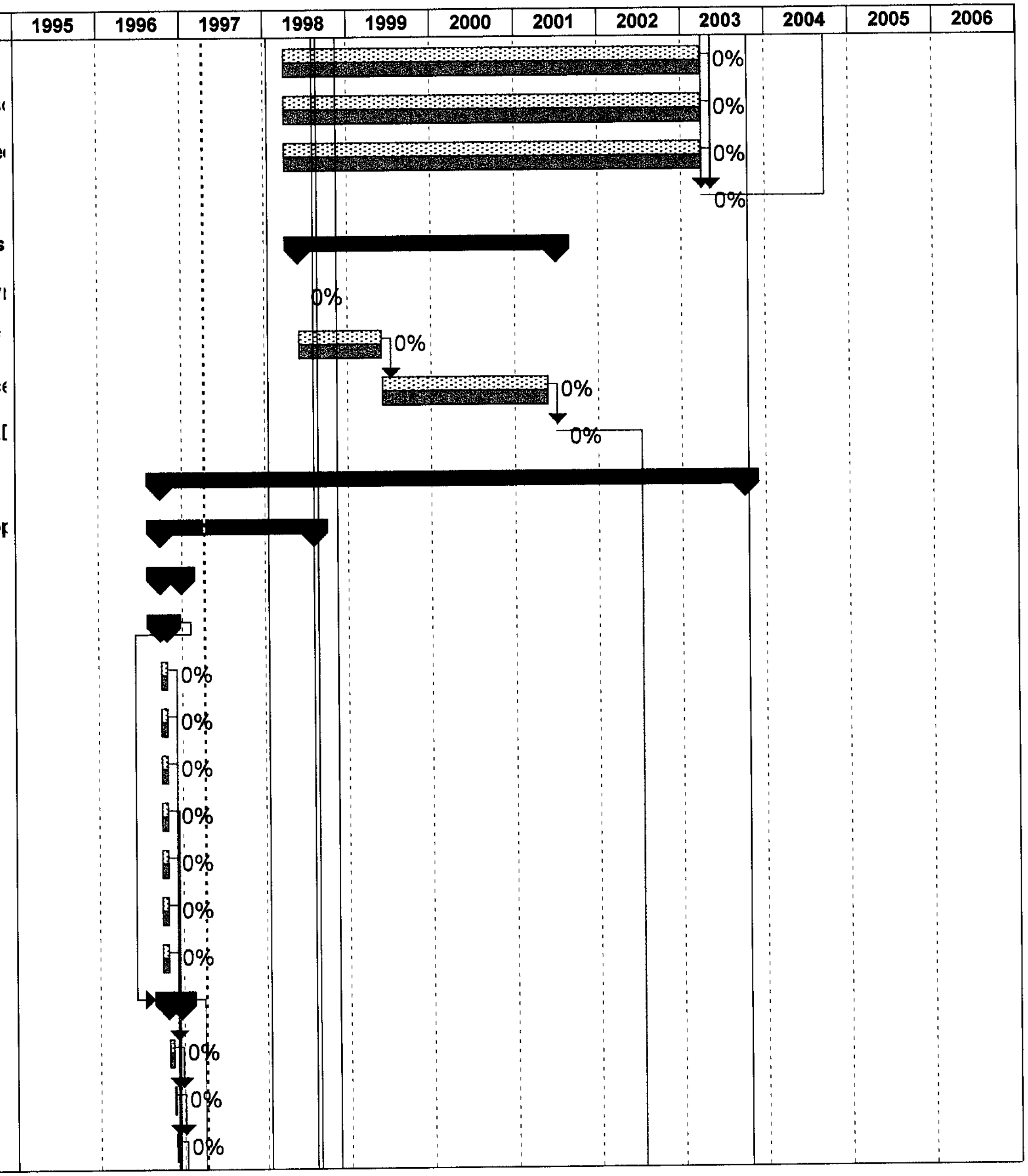
ID	WBS	Task Name
216	7.1.2.4.4	Monitor soil quality changes across second scale-up
217	7.1.2.4.5	Monitor regional level water quality effects of second s
218	7.1.2.4.6	Document biodiversity and wildlife habitat effects in se
219	7.1.2.4.7	Provide guidelines to demonstration project growers
220	**7.1.2.5**	**Establish switchgrass quality variation for ethanol convers**
221	7.1.2.5.1	Identify feedstock characteristics relevant to SSF enzy
222	7.1.2.5.2	Collect Samples from field trials representing range of
223	7.1.2.5.3	Analyze feedstock samples for effects on ethanol proc
224	7.1.2.5.4	Handoff information & samples to ethanol process R&I
225	**7.2**	**Biomass Conversion Technology**
226	**7.2.1**	**Softwood-specific process integration and process develo**
227	**7.2.1.1**	**Preliminary Technology Analysis**
228	**7.2.1.1.1**	**Investigate technologies**
229	7.2.1.1.1.1	SO2 steam explosion
230	7.2.1.1.1.2	Dilute acid hydrolysis
231	7.2.1.1.1.3	Concentrated acid
232	7.2.1.1.1.4	ACOS Organosolv process
233	7.2.1.1.1.5	Enzyme production
234	7.2.1.1.1.6	Fermentation/SHF/SSF
235	7.2.1.1.1.7	Lignin utilization
236	**7.2.1.1.2**	**Model 5 process options for softwoods**
237	7.2.1.1.2.1	Complete process & economic model
238	7.2.1.1.2.2	Option A
239	7.2.1.1.2.3	Option B



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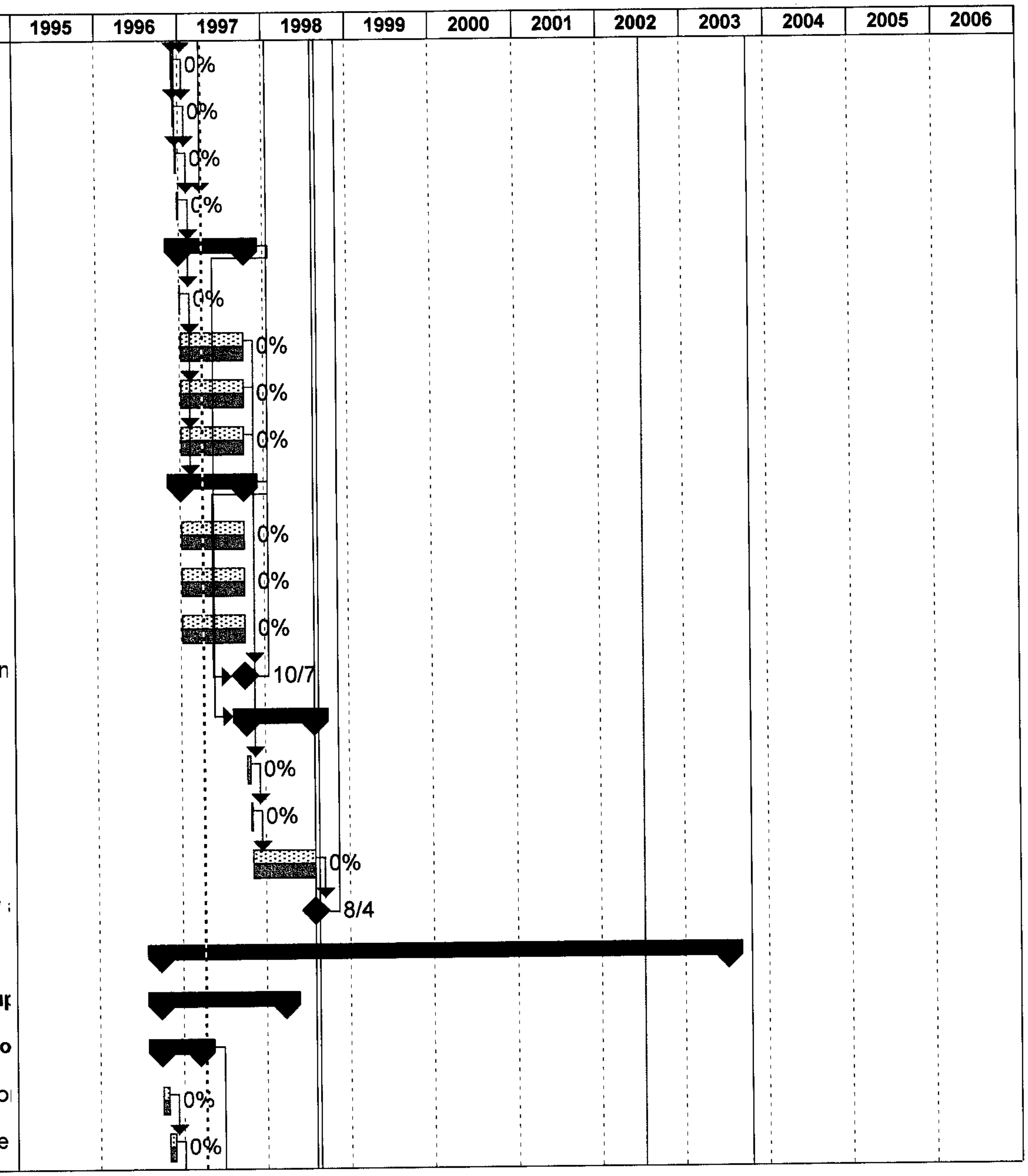
ID	WBS	Task Name
240	7.2.1.1.2.4	Option C
241	7.2.1.1.2.5	Option D
242	7.2.1.1.2.6	Option E
243	7.2.1.1.3	Identify technology gaps
244	**7.2.1.2**	**Fill Technology Gaps for Softwoods**
245	7.2.1.2.1	Revise softwoods technology plan
246	7.2.1.2.2	Subcontract or CRADA with UBC
247	7.2.1.2.3	Subcontract #2
248	7.2.1.2.4	Subcontract #3
249	**7.2.1.2.5**	**Pretreatment & fermentation work at NREL**
250	7.2.1.2.5.1	Dilute acid pretreatment
251	7.2.1.2.5.2	SO2 Steam explosion
252	7.2.1.2.5.3	C6 Fermentation R&D
253	7.2.1.2.6	Preliminary assessment of integrated technologies con
254	**7.2.1.3**	**Process Selection and PDU Testing**
255	7.2.1.3.1	Revise Process Models
256	7.2.1.3.2	Select Process for further development
257	7.2.1.3.3	Subcontract #4
258	7.2.1.3.4	Integrated process for softwood to ethanol technology :
259	**7.2.2**	**Process Integration and Process Development**
260	**7.2.2.1**	**Provide commercial development facility capabilities to sup**
261	**7.2.2.1.1**	**Demonstrate an integrated process for ethanol from cellulo**
262	7.2.2.1.1.1	Establish complete integrated process flow diagram fo
263	7.2.2.1.1.2	Prove that aseptic conditions can be maintained in the



Critical Path Analysis for Switchgrass Technology Baseline Plan
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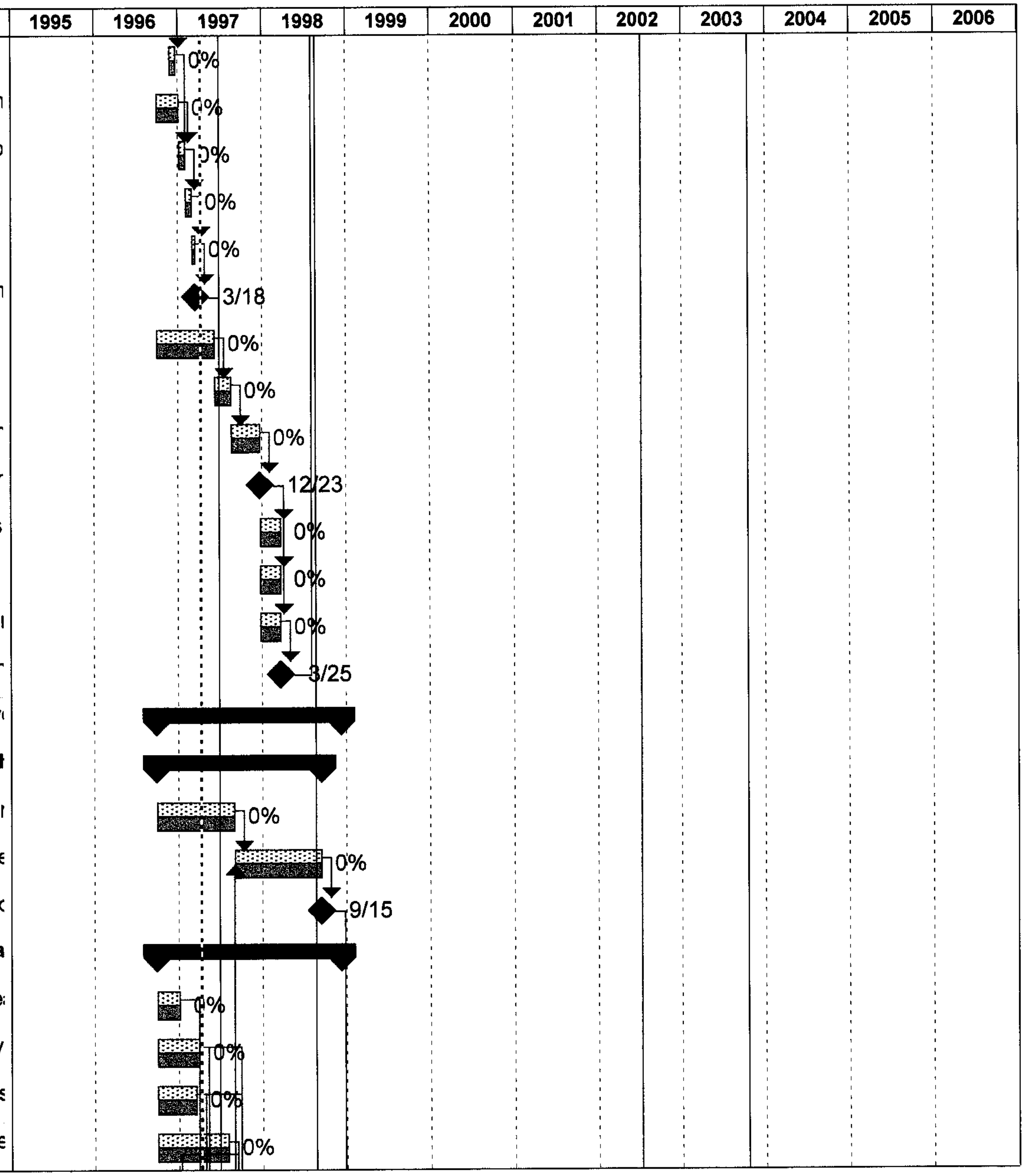
ID	WBS	Task Name
264	7.2.2.1.1.3	Obtain approval to operate the mini-pilot plant using a
265	7.2.2.1.1.4	Design, procure and test ion exchange equipment for h
266	7.2.2.1.1.5	Ready Sunds reactor to produce pretreated sawdust fo
267	7.2.2.1.1.6	Run process qualifier technology demonstration
268	7.2.2.1.1.7	Document process qualifier demonstration
269	7.2.2.1.1.8	Mini-pilot biochemical conversion unit available for con
270	7.2.2.1.2	Design full pilot plant scale detoxification equipment
271	7.2.2.1.3	Install full pilot plant scale detoxification equipment
272	7.2.2.1.4	Test and modify full pilot scale detoxification equipmer
273	7.2.2.1.5	Detoxification process available for pilot scale commer
274	7.2.2.1.6	Design SSCF system for pilot plant demonstration bas
275	7.2.2.1.7	Evaluate spent solids for combustion value
276	7.2.2.1.8	Investigate the impacts of gypsum on the bioethanol pı
277	7.2.2.1.9	Pilot scale testing capability available for use by comm
278	**7.2.2.2**	**Provide integrated process technology for commercial dev**
279	**7.2.2.2.1**	**Develop cellulase enzyme production technology utilizing I**
280	7.2.2.2.1.1	Establish cellulase production on hydrolysate and pretı
281	7.2.2.2.1.2	Improve cellulase production on hydrolysate and pretre
282	7.2.2.2.1.3	Cellulase enzyme production technology available for c
283	**7.2.2.2.2**	**Improve integrated process performance to achieve cost ta**
284	7.2.2.2.2.1	Produce pretreated and detoxified materials to meet te
285	7.2.2.2.2.2	Improve pretreatment to increase cellulose digestibility
286	7.2.2.2.2.3	Develop Zymomonas strain adapted to 100 % hydrolys
287	7.2.2.2.2.4	Complete detoxification process development at the be



Critical Path Analysis for Switchgrass Technology Baseline Plan
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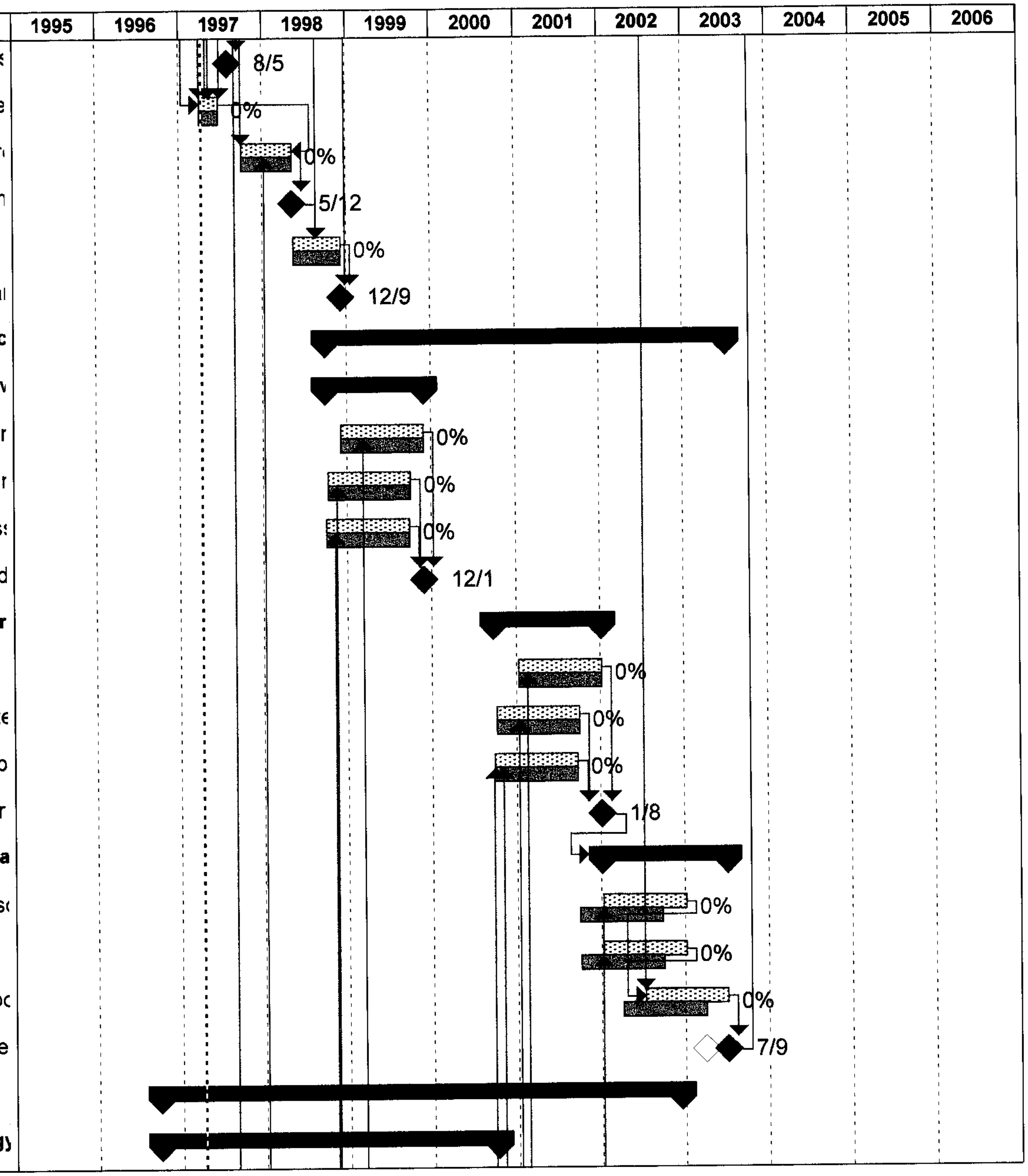
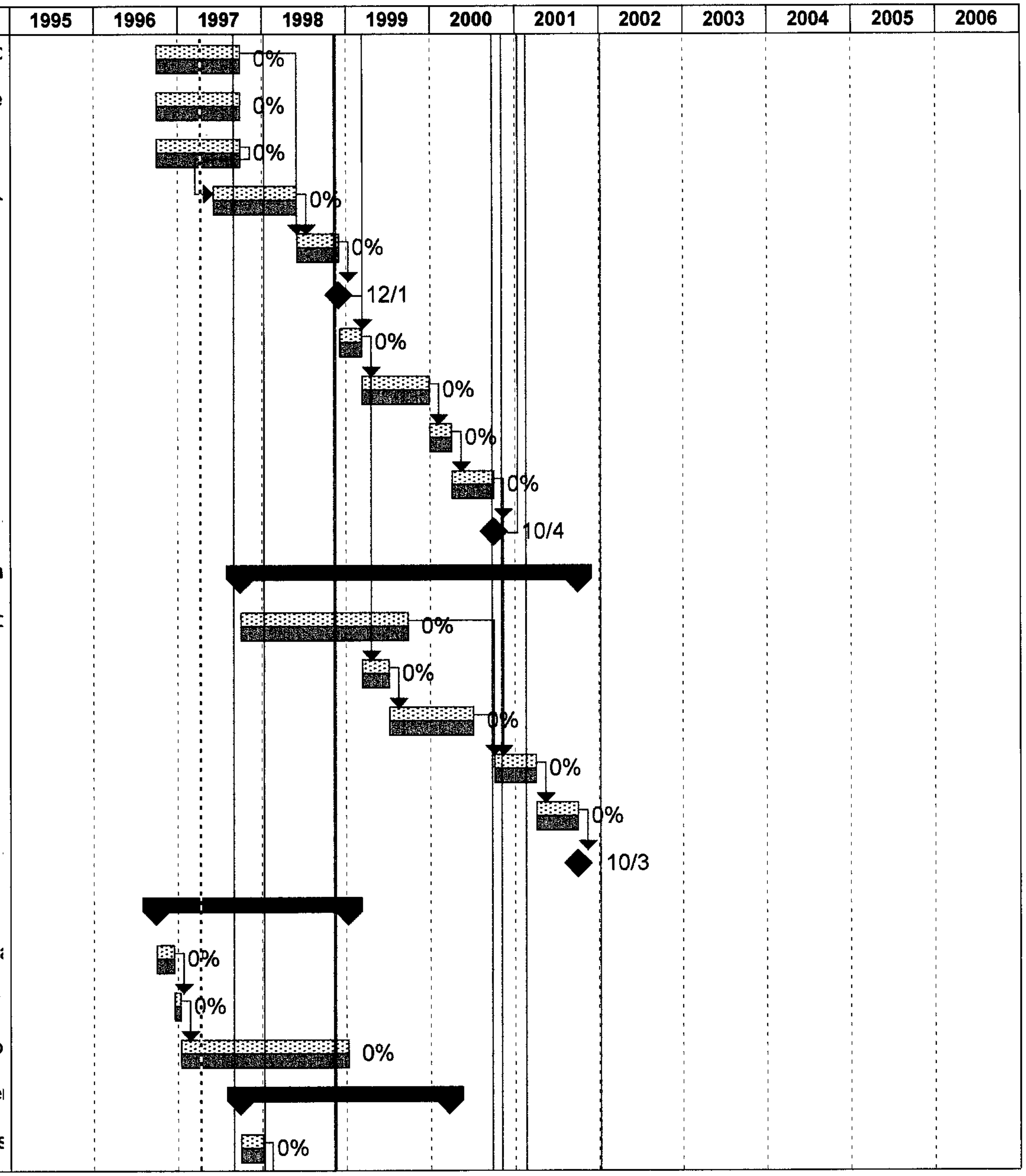
ID	WBS	Task Name
288	7.2.2.2.2.5	Provide data on applicability of detoxification to variou
289	7.2.2.2.2.6	Investigate SSCF performance by consideration of alte
290	7.2.2.2.2.7	Investigate SSCF performance utilizing improved pretr
291	7.2.2.2.2.8	Improved process technology ready for review and gen
292	7.2.2.2.2.9	Prioritized improvement projects carried out
293	.2.2.2.2.10	Integrated biomass to ethanol technology meeting yeai
294	**7.2.2.3**	**Test incremental improvements under integrated process c**
295	**7.2.2.3.1**	**First roll-out of improvements in technology for near term v**
296	7.2.2.3.1.1	Test first generation countercurrent prehydrolysis techr
297	7.2.2.3.1.2	Test Phase I genetically engineered cellulase system ir
298	7.2.2.3.1.3	Test improved Zymomonas strain in integrated proces
299	7.2.2.3.1.4	Documented improvements available for commercial d
300	**7.2.2.3.2**	**Second roll-out of improvements in technology for near ter**
301	7.2.2.3.2.1	Test lignin utilization technology
302	7.2.2.3.2.2	Test second generation countercurrent prehydrolysis te
303	7.2.2.3.2.3	Test "super" Zymomonas strain (robust) and/or Lactob
304	7.2.2.3.2.4	Improved low-value feedstock technology available for
305	**7.2.2.3.3**	**Develop integrated process for switchgrass conversion tha**
306	7.2.2.3.3.1	Test improvements in fermentor strains at the bench s
307	7.2.2.3.3.2	Test Phase II cellulase system at the bench scale
308	7.2.2.3.3.3	Integrate switchgrass to ethanol process at smallest pc
309	7.2.2.3.3.4	Switchgrass technology available for commercial deve
310	**7.2.3**	**Chemical Hydrolysis R&D**
311	**7.2.3.1**	**Develop countercurrent chemical prehydrolysis technology**



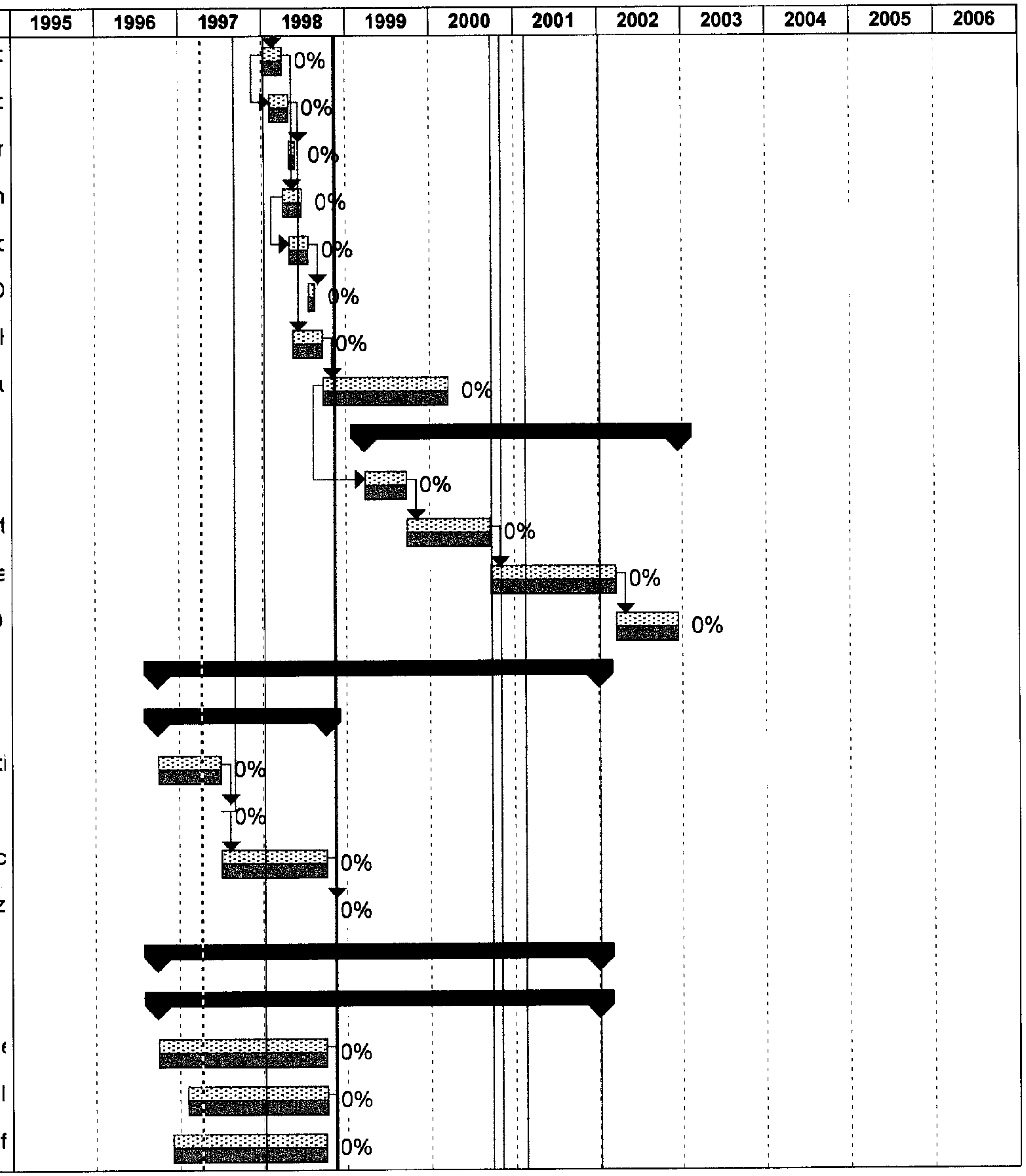
Critical Path Analysis for Switchgrass Technology Baseline Plan
Bioethanol Program Plan v24 Switchgrass Critical Path

ID	WBS	Task Name
312	7.2.3.1.1	Bench scale development of countercurrent chemical p
313	7.2.3.1.2	Supply test quantities of pretreated feedstocks for othe
314	7.2.3.1.3	Design and procure a prototype reactor
315	7.2.3.1.4	Modify, expand PDU and install and shakedown all equ
316	7.2.3.1.5	Test and modify prototype reactor
317	7.2.3.1.6	Hand-off prototype to EPD for integrated testing
318	7.2.3.1.7	Design second generation reactor
319	7.2.3.1.8	Procure second generation reactor
320	7.2.3.1.9	Install and shakedown second generation unit
321	7.2.3.1.10	Test and modify second generation unit
322	7.2.3.1.11	Hand-off second generation unit to EPD for integrated
323	**7.2.3.2**	**Develop countercurrent complete chemical hydrolysis tech**
324	7.2.3.2.1	Bench scale development of countercurrent complete c
325	7.2.3.2.2	Design complete hydrolysis reactor
326	7.2.3.2.3	Procure complete hydrolysis reactor
327	7.2.3.2.4	Install and shakedown complete hydrolysis reactor
328	7.2.3.2.5	Initial testing of complete hydrolysis reactor
329	7.2.3.2.6	Hand-off second generation unit to EPD for integrated
330	**7.2.3.3**	**Alternate Pretreatment Evaluation**
331	7.2.3.3.1	Complete Data Analysis and Process Economic Evalu
332	7.2.3.3.2	Develop Strategy for Follow-on Alternate Pretreatment
333	7.2.3.3.3	Further Development/Scale up/Testing of Selected Pro
334	**7.2.3.4**	**Long Term Feedstock (Hardwood) Bench Scale Developme**
335	7.2.3.4.1	Identify and Obtain Representative Hardwood Samples



Critical Path Analysis for Switchgrass Technology Baseline Plan
Bioethanol Program Plan v24 Switchgrass Critical Path

ID	WBS	Task Name
336	7.2.3.4.2	Determine Countercurrent Prehydrolysis Parameters fc
337	7.2.3.4.3	Determine Best Available Detox Methods for Hardwooc
338	7.2.3.4.4	Quantify Material Balance, Solids Digestibility and Ferr
339	7.2.3.4.5	Determine Countercurrent Complete Hydrolysis Param
340	7.2.3.4.6	Determine Best Available Detox Methods for Hardwooc
341	7.2.3.4.7	Quantify Material Balance and Fermentability of Std. D
342	7.2.3.4.8	Conduct Preliminary Process Engineering Analysis of I
343	7.2.3.4.9	Scale up Modification/Testing in Appropriate Countercu
344	**7.2.3.5**	**Long Range Advanced Pretreatment Technologies**
345	7.2.3.5.1	Identify Advanced Pretreatment Technologies
346	7.2.3.5.2	Conduct Bench Scale Development Program on Select
347	7.2.3.5.3	Identify and Obtain Appropriate Engineering Scale Rea
348	7.2.3.5.4	Testing of Advanced Pretreatment Technologies at PD
349	**7.2.4**	**Enzyme Technology R&D**
350	**7.2.4.1**	**Near Term Enzyme R&D**
351	7.2.4.1.1	T. reesei: Decrease cellulase cost by optimizing inducti
352	7.2.4.1.2	Deliver new protocols to EPD
353	7.2.4.1.3	T. reesei: Determine effects of induction protocols on c
354	7.2.4.1.4	Report correlation between T. reesei induction and enz
355	**7.2.4.2**	**Mid Term Enzyme R&D**
356	**7.2.4.2.1**	**Develop cost effective enzyme system for pretreated SG**
357	7.2.4.2.1.1	Phase I: Improve action of EI on pSG using site-directe
358	7.2.4.2.1.2	Phase I: Increase Topt and process tolerance of CBH I
359	7.2.4.2.1.3	Perform substrate/cellulose binding domain modeling f

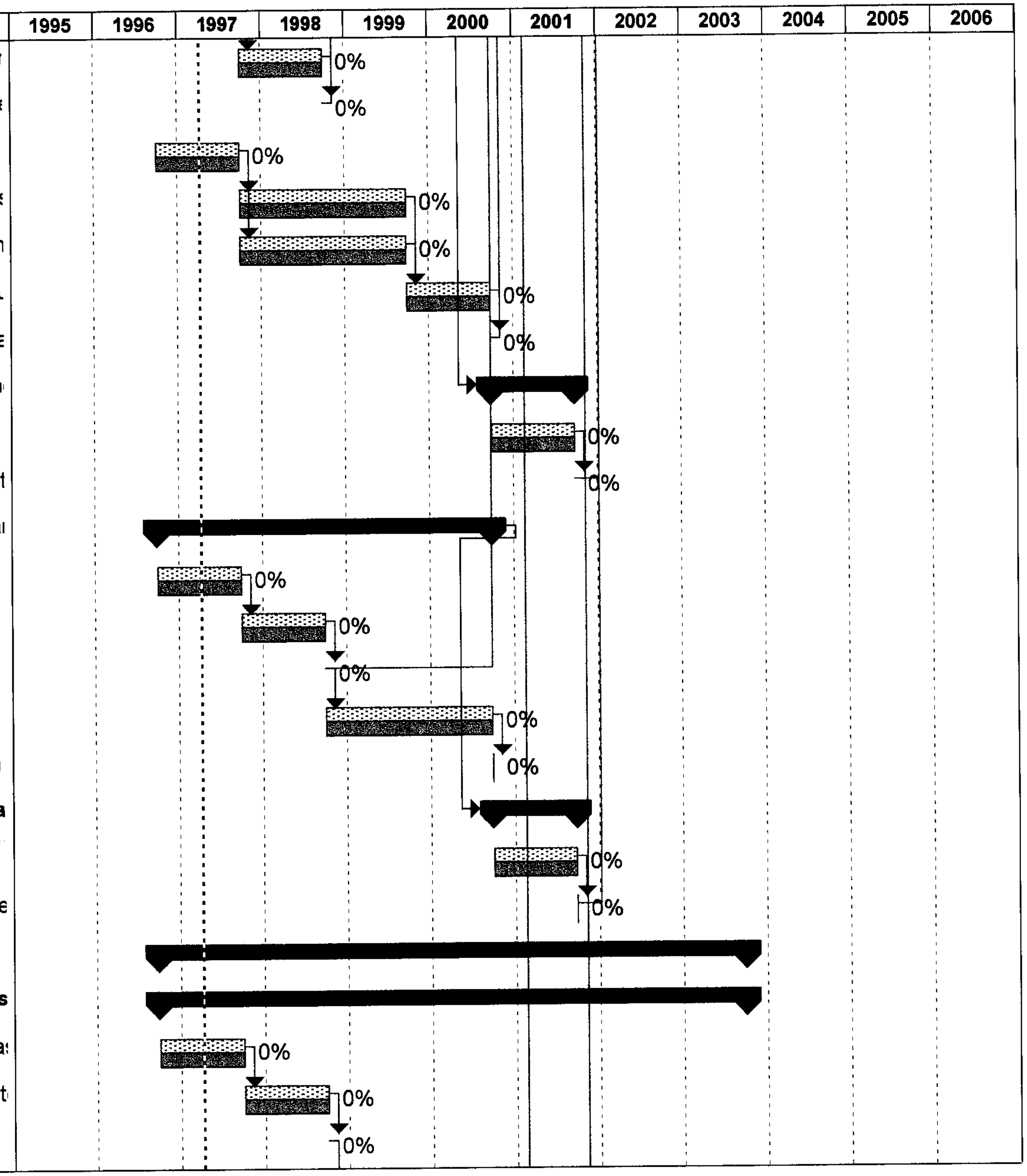


Critical Path Analysis for Switchgrass Technology Baseline Plan
Bioethanol Program Plan v24 Switchgrass Critical Path

ID	WBS	Task Name	
360	7.2.4.2.1.4	Phase I: Increase Topt and process tolerance of E3 us	0%
361	7.2.4.2.1.5	Provide high resolution x-ray structure for E3 and clon	0%
362	7.2.4.2.1.6	Report K Milestone describing cellulase improvement t	0%
363	7.2.4.2.1.7	Deliver Phase I engineered cellulase system to EPD fo	0%
364	7.2.4.2.1.8	DECISION: Pick plant or submerged culture expressio	0%
365	7.2.4.2.1.9	Develop strategy to improve active site performance of	0%
366	.2.4.2.1.10	Phase II: Increase specific activity of CBHI on pSG usi	0%
367	.2.4.2.1.11	Phase II: Increase specific activity of E3 on pSG using	0%
368	.2.4.2.1.12	Deliver Phase II engineered cellulase system w access	0%
369	.2.4.2.1.13	DECISION: Pick enzymes or DMC	0%
370	.2.4.2.1.14	Deliver technology for plant produced cellulases to EPI	0%
371	.2.4.2.1.15	Provide purified accessory enz for testing at NREL	0%
372	.2.4.2.1.16	Determine utility of accessory enz (xylanases, cellodex	0%
373	.2.4.2.1.17	Improve Topt and process tolerance of accessory enzy	0%
374	.2.4.2.1.18	Produce rEI, rCBHI, and E3 in submerged culture (Asp	0%
375	.2.4.2.1.19	Produce Phase I rEI, rCBHI, rE3, and/or accessory enz	0%
376	.2.4.2.1.20	Evaluate Gen II submerged culture production technol	0%
377	.2.4.2.1.21	Deliver mature technology for submerged culture prodi	0%
378	.2.4.2.1.22	Evaluate new engineered cellulase/accessory enz syst	0%
379	.2.4.2.1.23	Evaluate enzymes expressed from best plant and/or su	0%
380	**7.2.5**	**Fermentation Organism Development**	
381	**7.2.5.1**	**Develop Zymomonas Organism for use in year 2000 waste**	
382	7.2.5.1.1	Evaluate new new Zymomonas strains	0%
383	7.2.5.1.2	Select strains for hand-off to integration studies	9/29

Critical Path Analysis for Switchgrass Technology Baseline Plan
Bioethanol Program Plan v24 Switchgrass Critical Path

ID	WBS	Task Name
384	7.2.5.1.3	Develop further improvements to Zymomonas organisı
385	7.2.5.1.4	Hand-off improved Zymomonas strain for pilot scale d
386	7.2.5.1.5	Investigate new approaches to improving Zymomonas
387	7.2.5.1.6	Begin making metabolic enhancements of Zymomonas
388	7.2.5.1.7	Implement strategies to improve robustness of Zymom
389	7.2.5.1.8	Develop a "super" Zymomonas strain with desired robu
390	7.2.5.1.9	Hand-off advanced Zymomonas strains to industrial pa
391	**7.2.5.2**	**Develop Zymomonas Organism for use in year 2005 switch**
392	7.2.5.2.1	Make adjustments switchgrass
393	7.2.5.2.2	Hand-off switchgrass Zymomonas strain to EPD for int
394	**7.2.5.3**	**Develop a Lactobacillus strain for improved performance a**
395	7.2.5.3.1	Re-initiate work on lactobacillus
396	7.2.5.3.2	Develop an ethanol producing lactobacillus
397	7.2.5.3.3	Hand-off lactobacillus to EPD for integration and PDU
398	7.2.5.3.4	Assess and improve lactobacillus strains
399	7.2.5.3.5	Hand-off lactobacillus organism to EPD for integration
400	**7.2.5.4**	**Develop Lactobacillus strain for use in year 2005 switchgra**
401	7.2.5.4.1	Make adjustments for switchgrass sugars as needed
402	7.2.5.4.2	Hand-off switchgrass Lactobacillus strain to EPD for te
403	**7.2.6**	**Direct Microbial Conversion Strain Development**
404	**7.2.6.1**	**Develop cost effective Zymomonas strains for DMC proces**
405	7.2.6.1.1	Acquire or produce cDNA clone of best beta-glucosida
406	7.2.6.1.2	Clone cellobiase in best "Z" using best expression vect
407	7.2.6.1.3	Deliver cellobiose fermenting "Z" to EPT for testing



Critical Path Analysis for Switchgrass Technology Baseline Plan
Bioethanol Program Plan v24 Switchgrass Critical Path

ID	WBS	Task Name
408	7.2.6.1.4	Develop integrated transformation system for Z, using
409	7.2.6.1.5	Clone rEI and rCBHI in best "Z" or Lactobacillus
410	7.2.6.1.6	Deliver engineered "Z" or Lactobacillus to EPT for testi
411	**7.2.7**	**Lignin Utilization R & D**
412	7.2.7.1	Technoeconomic analysis
413	7.2.7.2	Lab optimization of BCD
414	7.2.7.3	Reproducibility and batch scale-up
415	7.2.7.4	Supply lignin to Utah, Sandia and NREL
416	7.2.7.5	Jet reactor BCD process work
417	7.2.7.6	Analysis of BCD products
418	7.2.7.7	Detailed flow diagram: BCD/HPR
419	7.2.7.8	Detailed flow diagram:E+SHR
420	7.2.7.9	Evaluation/ determine product targets
421	7.2.7.10	Technoeconomic analysis of best products
422	7.2.7.11	Scale-up of jet or other reactor
423	7.2.7.12	Pilot plant testing of new reactor

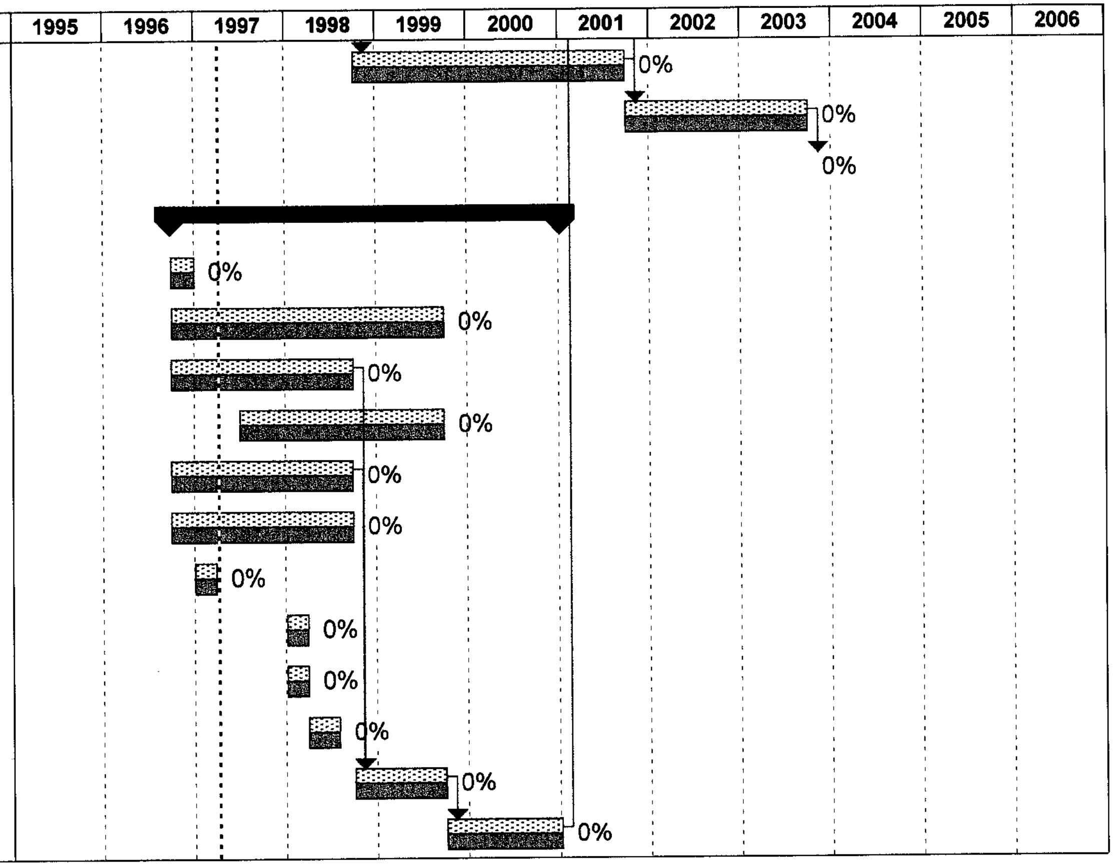
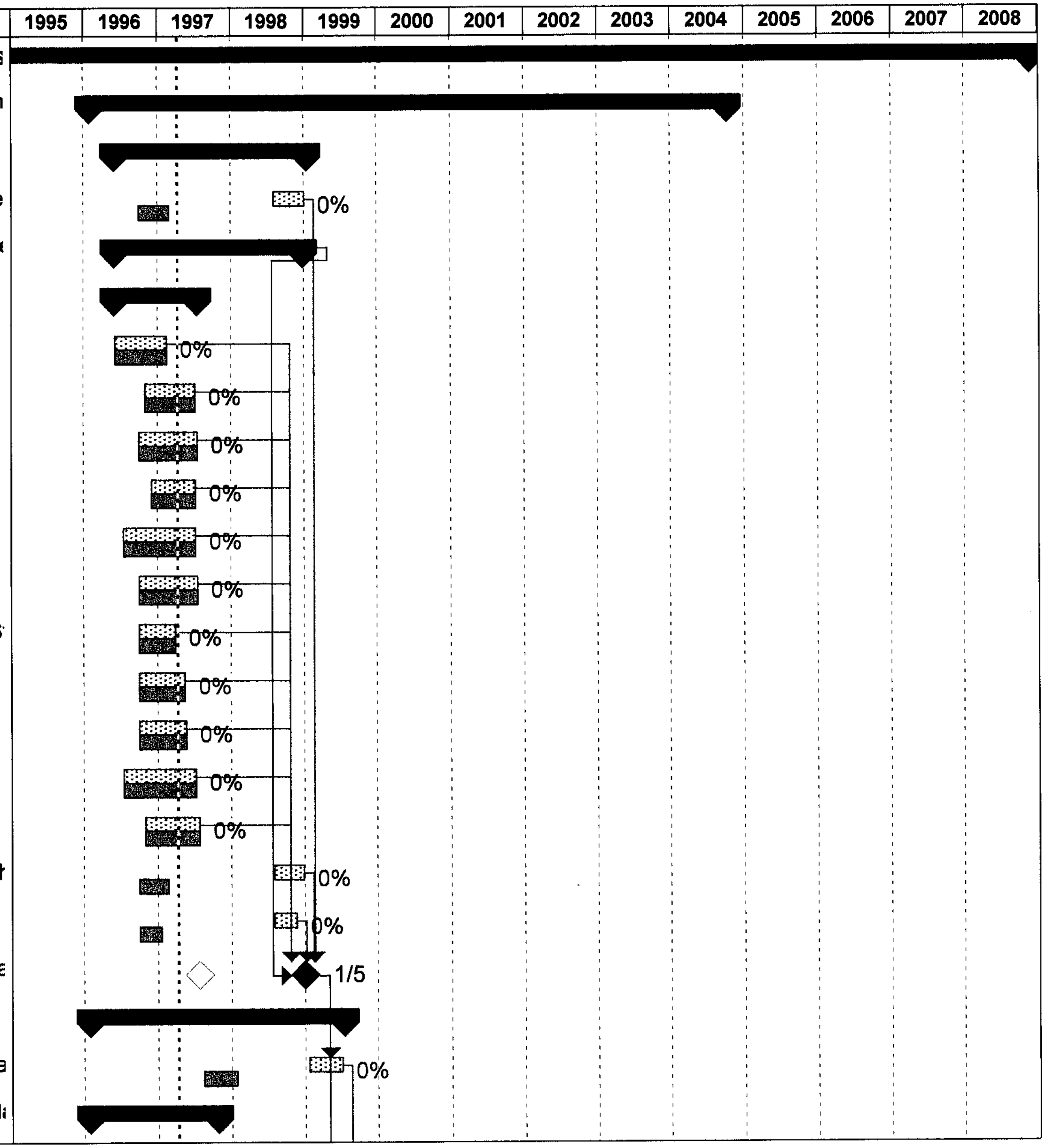


Figure 27: Ethanol Multi-Year Technical Plan: Critical Path Analysis of Mid Term Deployment Goal in Resource-Leveled Plan

Shown on next 20 pages

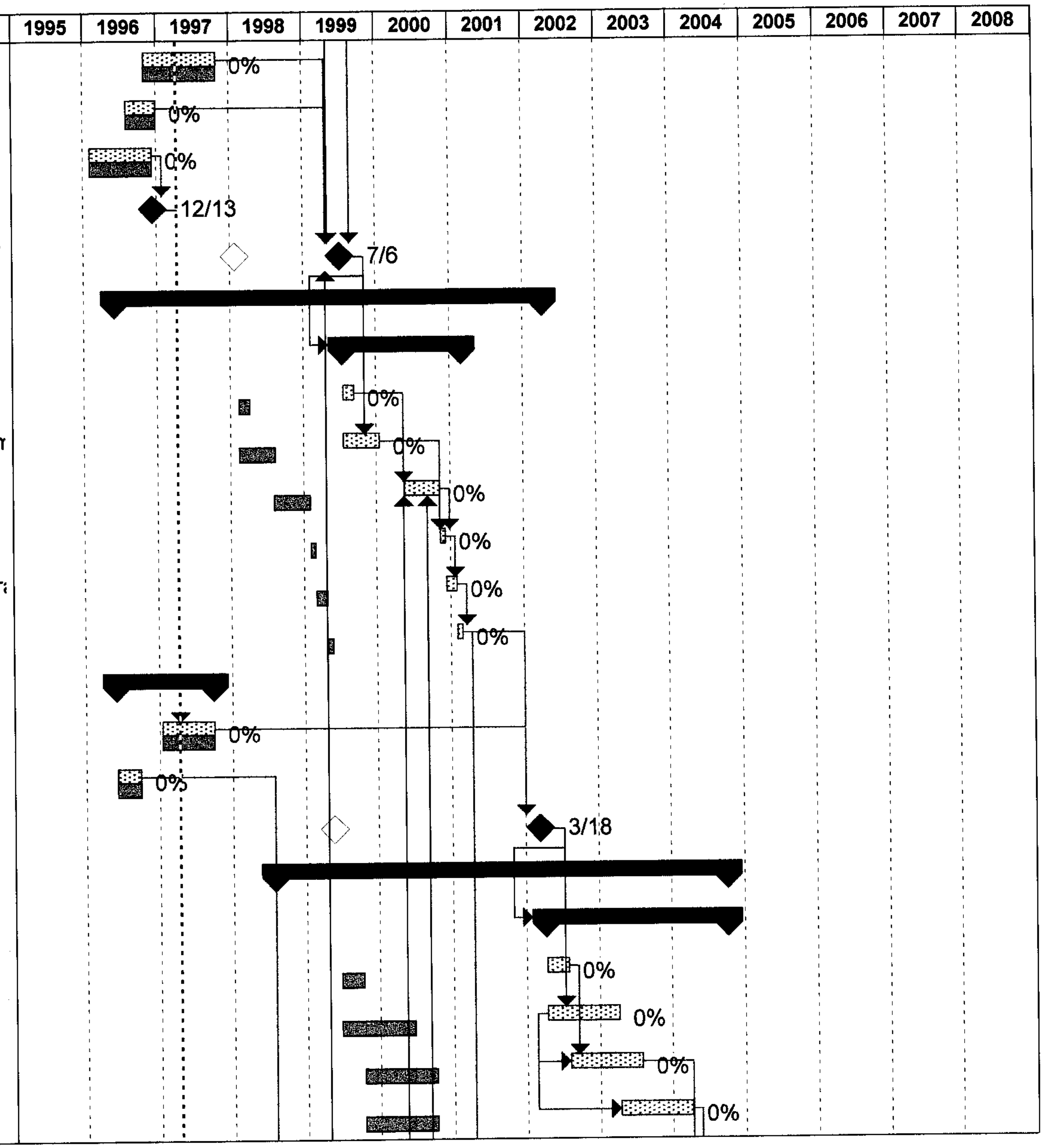
Critical Path Analysis for Switchgrass Technology
Resource-Leveled Plan
Bioethanol Program Plan v24 level Switchgrass Critical Path

ID	WBS	Task Name
	0	**Bioethanol Program Plan v24 level Switchgras**
1	1	**Commercially demonstrate waste biomass to ethanol techn**
2	1.1	**Preliminary Feasibility Studies**
3	1.1.1	Conduct New Preliminary Feasibility Studies (supporte
4	1.1.2	**Complete Existing Preliminary Feasibility Studies (support**
5	1.1.2.1	**Near term softwood opportunities**
6	1.1.2.1.1	Quincy Library Group Feasibility Study (softwood)
7	1.1.2.1.2	Colorado "Pine Zone" Feasibility Study (softwood)
8	1.1.2.1.3	2 contracts (TBD)
9	1.1.2.1.4	PALCO and LP Feasibility Studies (softwood)
10	1.1.2.1.5	IBI CRADA (softwood)
11	1.1.2.1.6	CARB Bioethanol Life Cycle Analysis (softwood)
12	1.1.2.1.7	Washington State Energy Office Pulp Mill Feasibility S
13	1.1.2.2	ACE Feasibility Study (CRP grass)
14	1.1.2.3	Iowa Feasibility Study (CRP grass)
15	1.1.2.4	Delta-T CRADA (feedstock to be determined)
16	1.1.2.5	Cellulase Partnership with logen
17	1.1.2.6	Quaker Oats Chemicals/Manildra Feasibility Study (otł
18	1.1.2.7	Pure Vision Feasibility Study (other feedstock)
19	1.1.3	Select Partners for Final Feasibility Studies (apply Fina
20	1.2	**Final Feasibility Studies**
21	1.2.1	Conduct New Final Feasibility Studies (supported by la
22	1.2.2	**Complete Existing Final Feasibility Studies (supported by la**



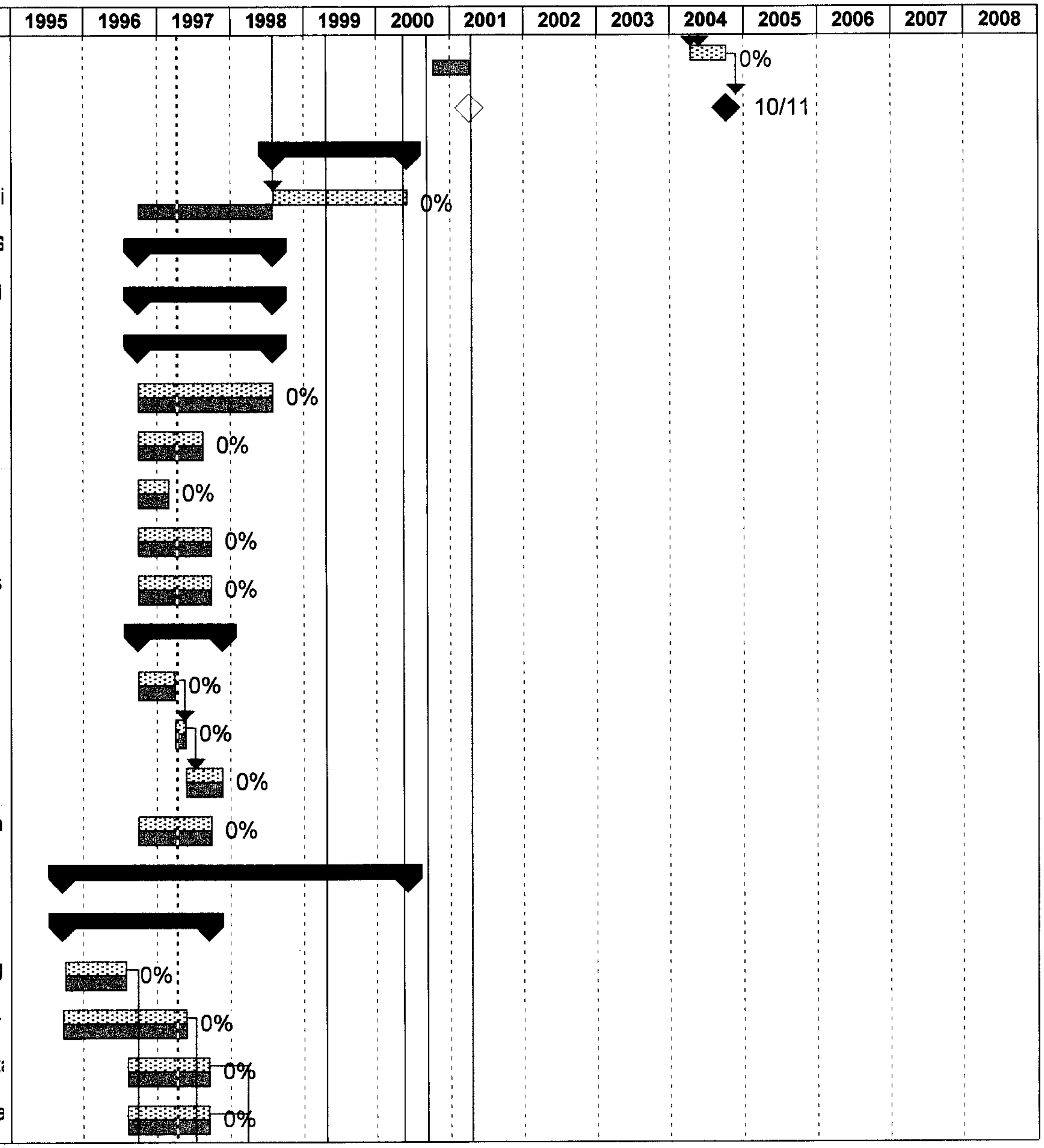
Critical Path Analysis for Switchgrass Technology
Resource-Leveled Plan
Bioethanol Program Plan v24 level Switchgrass Critical Path

ID	WBS	Task Name
23	1.2.2.1	Coors CRADA Phase 2 (grain milling residue)
24	1.2.2.2	New Energy CRADA (grain milling residue)
25	1.2.2.3	Gridley Project Phase 1 (rice straw)
26	1.2.2.4	Gridley Phase 2 Go/No-go Decision
27	1.2.3	Select Partners for Business Plan Development (apply
28	**1.3**	**Business Plans**
29	**1.3.1**	**Conduct New Business Plans**
30	1.3.1.1	Negotiate Legal Arrangements with Partners
31	1.3.1.2	Establish Feedstock/Product Contracts and Site Comm
32	1.3.1.3	Conduct PDU Testing and Data Analysis
33	1.3.1.4	Re-evaluate Process Design and Cost Estimate
34	1.3.1.5	Negotiate License Agreements and Performance Guar
35	1.3.1.6	Issue New Business Plans
36	**1.3.2**	**Complete Existing Business Plans**
37	1.3.2.1	Gridley Phase 2 - issue business plan
38	1.3.2.2	Amoco CRADA Phase 3
39	1.3.3	Select Partners for Demonstration Plant Development
40	**1.4**	**Demonstration Plants**
41	**1.4.1**	**Conduct New Demonstration Plant Efforts**
42	1.4.1.1	Finance Facility
43	1.4.1.2	Conduct Detailed Design
44	1.4.1.3	Obtain Permits
45	1.4.1.4	Construct Facility



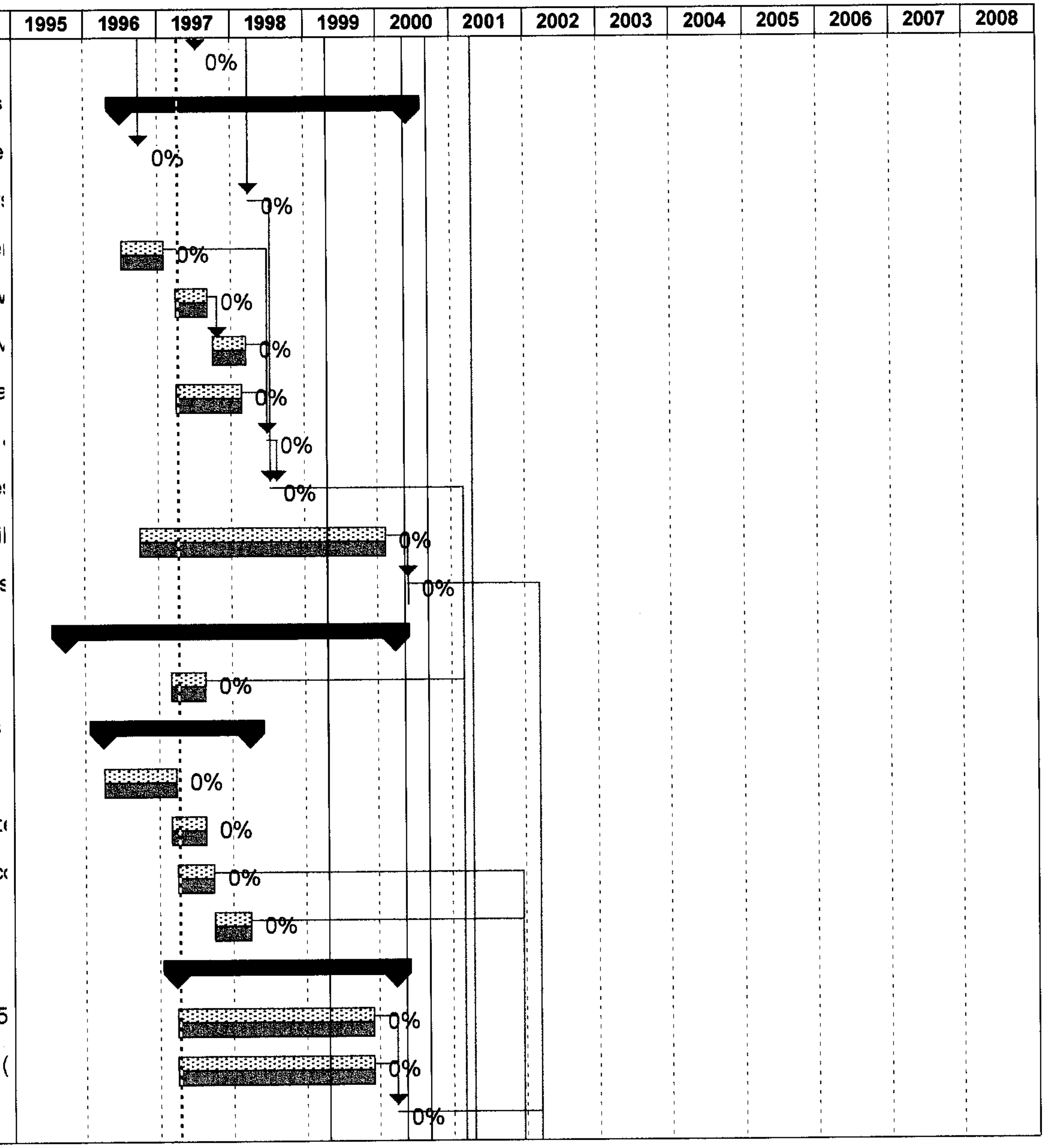
Critical Path Analysis for Switchgrass Technology
Resource-Leveled Plan
Bioethanol Program Plan v24 level Switchgrass Critical Path

ID	WBS	Task Name
46	1.4.1.5	Start Up Facility by Year 2000
47	1.4.1.6	Commercial Operation
48	**1.4.2**	**Complete Existing Demonstration Plant Efforts**
49	1.4.2.1	Amoco CRADA Phase 4 - Final Report on Demonstrati
50	**2**	**Develop and Maintain PDT Capabilities and Data Bases to S**
51	**2.1**	**PDT Tools, Data Bases and Capabilities to Conduct Feasibi**
52	**2.1.1**	**Develop Data Base for Near-Term Feedstock**
53	2.1.1.1	Develop Forest Residue GIS Database
54	2.1.1.2	Develop Saw & Pulp Mill GIS Database
55	2.1.1.3	Montana State Wood Waste Assessment
56	2.1.2	Maintain PDT Engineering/Economic Analysis Models
57	2.2	Develop Data Base for Sources of Funding to Partners
58	**3**	**Establish Partnerships for Long-Term Research**
59	3.1	Determine Key Long-Term Research Objectives
60	3.2	Determine Who Should Conduct Research to Achieve
61	3.3	Establish Partnerships with Non-NREL Entities
62	4	Coordinate With Federal, State, Local & Private Organ
63	**5**	**Develop Switchgrass Partnerships for Ethanol Production**
64	**5.1**	**Identify potential locations for crop supplies at $42/dry ton**
65	5.1.1	Complete crop economic baselines at national and reg
66	5.1.2	Complete integrated GIS analysis in selected states (4
67	5.1.3	Complete Integrated GIS analysis of potential in 14 st
68	5.1.4	Complete preliminary waste and feedstock supply data



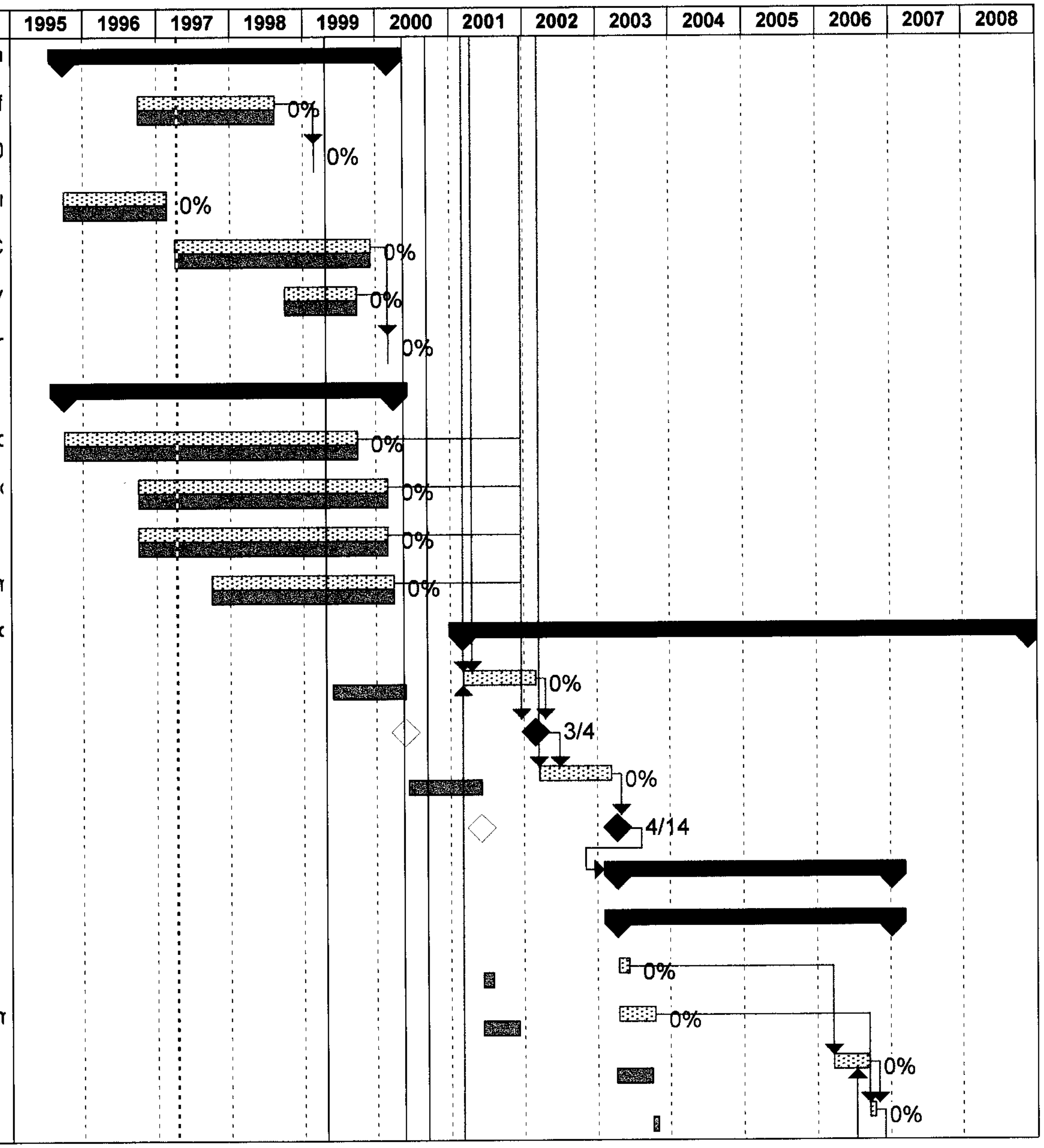
Critical Path Analysis for Switchgrass Technology
Resource-Leveled Plan
Bioethanol Program Plan v24 level Switchgrass Critical Path

ID	WBS	Task Name
69	5.1.5	Recommend locations for focused R&D, scale-up and
70	**5.2**	**Assist feasibility studies with integrated analysis products**
71	5.2.1	Provide integrated crop economic models for develope
72	5.2.2	Provide results of GIS model runs to states, developer:
73	5.2.3	Provide feedstock supply curves for ethanol market pe
74	5.2.4	Collaborate with USDA on putting switchgrass & SRW
75	5.2.5	Use USDA models for improving feedstock supply curv
76	5.2.6	Integrate cost & production risks in farmer decision ma
77	5.2.7	Publish crop supply models and scenario results (4.01
78	5.2.8	Recommend locations for preliminary feasibility studie:
79	5.2.9	Update crop economic info as new data becomes avail
80	5.2.10	Release updated crop economic models for developers
81	**5.3**	**Expand switchgrass supply system expertise & interest**
82	5.3.1	Summarize and publish results of first 5 yrs SG R&D
83	**5.3.2**	**Expand number and scale of switchgrass testing locations**
84	5.3.2.1	Farmer participation in Chariton Valley, Iowa secured
85	5.3.2.2	Renegotiate Univ. contracts to include scale-ups & sat
86	5.3.2.3	Negotiate extending variety testing & breeding to Wisc
87	5.3.2.4	USDA Plant Materials Center Participation Secured
88	**5.3.3**	**Predict switchgrass market potential for feasibility studies**
89	5.3.3.1	Link ISU economics experts with Chariton RC&D (5.05
90	5.3.3.2	Link ag economics expertise with other scale-up sites (
91	5.3.3.3	Provide economic info for final feasibility studies



Critical Path Analysis for Switchgrass Technology
Resource-Leveled Plan
Bioethanol Program Plan v24 level Switchgrass Critical Path

ID	WBS	Task Name
92	**5.3.4**	**Predict environmental effects of switchgrass supply systen**
93	5.3.4.1	Develop models for national/regional environmental eff
94	5.3.4.2	Model & predict regional level water quality effects (4.0
95	5.3.4.3	Collect & evaluate info on soil nutrient and carbon chai
96	5.3.4.4	Model erosion and water quality effects in Iowa (CVRC
97	5.3.4.5	Compare SG & alt. crop environmental effects from av
98	5.3.4.6	Publish preliminary predictions of env. effects of switcł
99	**5.3.5**	**Stimulate producer interest in business plan development**
100	5.3.5.1	Develop farmer oriented news outlets, hold news broac
101	5.3.5.2	Conduct field days and workshops for farmers & devel‹
102	5.3.5.3	Develop networks with farmers and developers (5.0)
103	5.3.5.4	Educate public, developers, policy makers on environn
104	**6**	**Commercially demonstrate switchgrass to ethanol technolc**
105	6.1	Preliminary feasibility studies
106	6.2	Select partners for final feasibility studies
107	6.3	Final feasibility studies
108	6.4	Select partners for business plan development
109	**6.5**	**Business Plans**
110	**6.5.1**	**Conduct New Business Plans**
111	6.5.1.1	Negotiate Legal Arrangements with Partners
112	6.5.1.2	Establish Feedstock/Product Contracts and Site Comn
113	6.5.1.3	Conduct PDU Testing and Data Analysis
114	6.5.1.4	Re-evaluate Process Design and Cost Estimate



Critical Path Analysis for Switchgrass Technology
Resource-Leveled Plan
Bioethanol Program Plan v24 level Switchgrass Critical Path

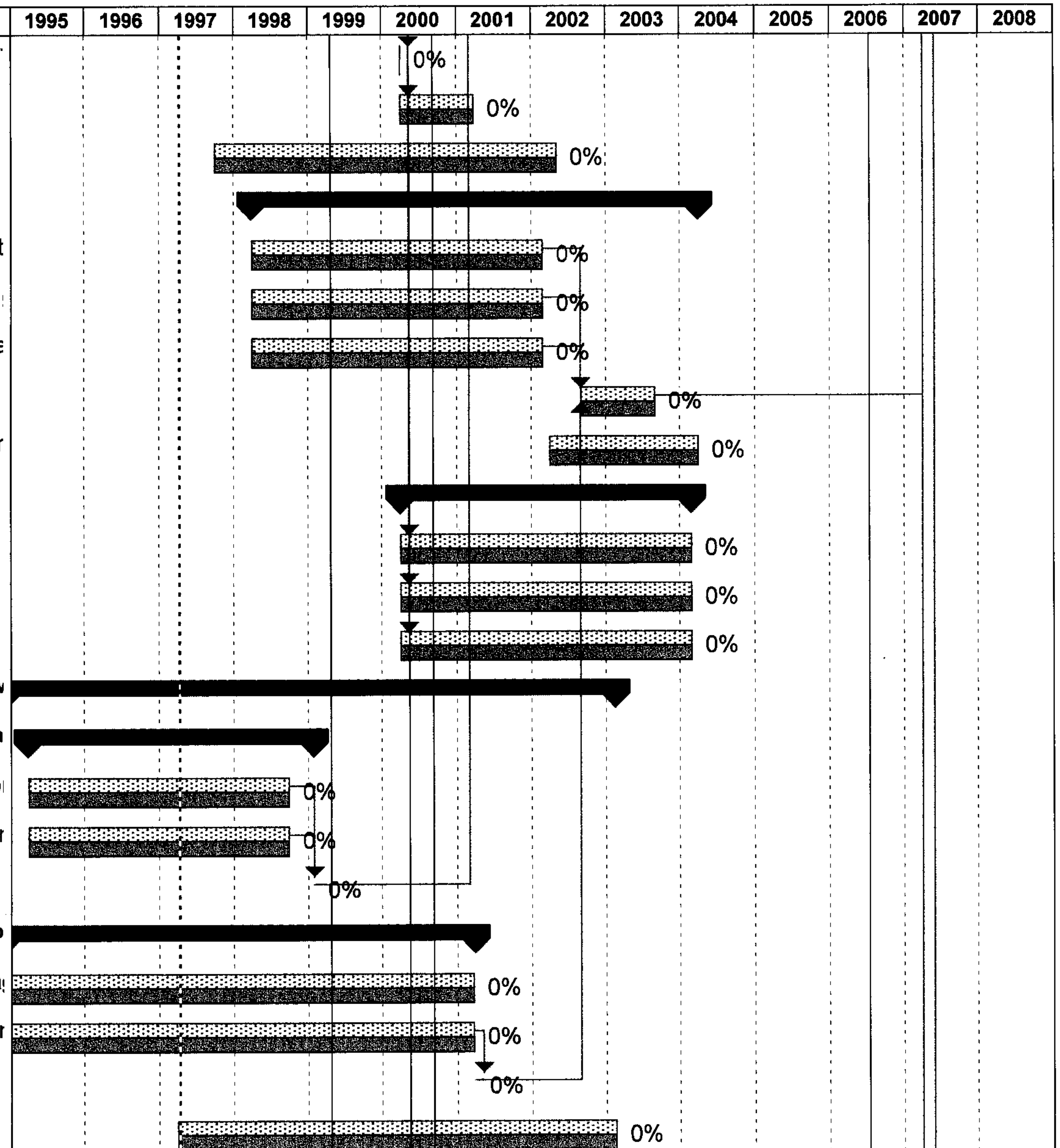
ID	WBS	Task Name
115	6.5.1.5	Negotiate License Agreements and Performance Guar:
116	6.5.1.6	Issue New Business Plans
117	6.6	Select Partners for Demonstration Plant Development
118	**6.7**	**Demonstration Plants**
119	**6.7.1**	**Agricultural Production**
120	6.7.1.1	Establish Feedstock Supply Contracts & Financing
121	6.7.1.2	Fall site preparation & secure seed
122	6.7.1.3	Spring site preparation & planting
123	6.7.1.4	First year harvest (stored for start-up runs)
124	6.7.1.5	Evaluate supply & contract for wastes if necessary
125	6.7.1.6	Second year harvest;pre-commercial start-up
126	**6.7.2**	**Conduct New Demonstration Plant Efforts**
127	6.7.2.1	Finance Facility
128	6.7.2.2	Conduct Detailed Design
129	6.7.2.3	Obtain Permits
130	6.7.2.4	Construct Facility
131	6.7.2.5	Start Up Facility by Year 2005
132	6.7.2.6	Commercial Operation
133	**7**	**Core Technology Development**
134	**7.1**	**Switchgrass Feedstock Production Technology**
135	**7.1.1**	**Support Switchgrass Crop Development Centers in at least**
136	**7.1.1.1**	**Identify best varieties and yield potential**
137	**7.1.1.1.1**	**Screen for best varieties in South & Mid-Atlantic States**

Critical Path Analysis for Switchgrass Technology
Resource-Leveled Plan
Bioethanol Program Plan v24 level Switchgrass Critical Path

ID	WBS	Task Name	1995–2008
138	7.1.1.1.1.1	Screen available varieties at 19 sites for high& sustain	0%
139	7.1.1.1.1.2	Recommend best varieties for first scale-up & breeding	0%
140	7.1.1.1.1.3	Expand variety screening to 13 other states	0%
141	**7.1.1.1.2**	**Screen for best varieties & locations in NC & NE/L states**	
142	7.1.1.1.2.1	Screen available varieties in Nebraska for high & susta	0%
143	7.1.1.1.2.2	Recommend best varieties for first scale-up & breeding	0%
144	7.1.1.1.2.3	Screen available varieties in Wisconsin for high & sust	0%
145	7.1.1.1.2.4	Expand variety screening to 10 other states	0%
146	**7.1.1.2**	**Optimize culture to improve yields & benefit environment**	
147	**7.1.1.2.1**	**Test culture effects in Southern & Mid-Atl. experiments 1-1**	
148	7.1.1.2.1.1	Identify establishment & fertilizer requirements (2.02,2.	0%
149	7.1.1.2.1.2	Provide preliminary crop mgm guidelines for R&D scal	0%
150	7.1.1.2.1.3	Identify nutrient factors affecting yield & quality (2.02, 2	0%
151	7.1.1.2.1.4	Identify harvest factors affecting yield & quality (2.02, 2	0%
152	7.1.1.2.1.5	Provide improved crop mgm guidelines for feasibility s	0%
153	7.1.1.2.1.6	Use data to improve econ., env, and supply models	0%
154	7.1.1.2.1.7	Repeat above in 13 other states with extension links	0%
155	**7.1.1.2.2**	**Test culture effects in NC experiments 1-10 acre**	
156	7.1.1.2.2.1	Identify establishment & fertilizer requirements (2.07)	0%
157	7.1.1.2.2.2	Provide preliminary crop mgm guidelines to growers fc	0%
158	7.1.1.2.2.3	Identify nutrient factors affecting yield & quality (2.08)	0%
159	7.1.1.2.2.4	Identify harvest factors affecting yield and quality (2.08	0%
160	7.1.1.2.2.5	Develop information necessary to register new herbicic	0%

Critical Path Analysis for Switchgrass Technology
Resource-Leveled Plan
Bioethanol Program Plan v24 level Switchgrass Critical Path

ID	WBS	Task Name
161	7.1.1.2.2.6	Provide improved crop mgm guidelines for feasibility s
162	7.1.1.2.2.7	Use data to improve econ., env., and supply models
163	7.1.1.2.2.8	Repeat above in 13 other states with extension links
164	**7.1.1.2.3**	**Improve culture through understanding mechanisms**
165	7.1.1.2.3.1	Develop mechanistic understanding of yield response t
166	7.1.1.2.3.2	Develop mechanistic understanding of responses to m
167	7.1.1.2.3.3	Develop information on value of ash & wastes as soil a
168	7.1.1.2.3.4	Use information to improve culture guidelines
169	7.1.1.2.3.5	Use information to improve national feedstock supply r
170	**7.1.1.2.4**	**Adapt culture to potential locations for commercial demos**
171	7.1.1.2.4.1	Identify best establishment techniques for locations
172	7.1.1.2.4.2	Test range of fertilizer levels & methods of appl.
173	7.1.1.2.4.3	Test herbicide types, rates, & appl. methods
174	**7.1.1.3**	**Evaluate environmental effects of culture techniques at few**
175	**7.1.1.3.1**	**Develop SE management options for environmentally soun**
176	7.1.1.3.1.1	Evaluate surface & subsurface water quality as functio
177	7.1.1.3.1.2	Evaluate soil quality responses as function of manager
178	7.1.1.3.1.3	Provide site mgm/env guidelines to growers & EPA
179	**7.1.1.3.2**	**Develop NC site management options for environmental so**
180	7.1.1.3.2.1	Evaluate subsurface water quality as function of mana
181	7.1.1.3.2.2	Evaluate soil quality responses as function of manager
182	7.1.1.3.2.3	Provide site mgm/env. guidelines to growers & EPA
183	7.1.1.3.3	Educate multiple groups on environmental benefits



Critical Path Analysis for Switchgrass Technology
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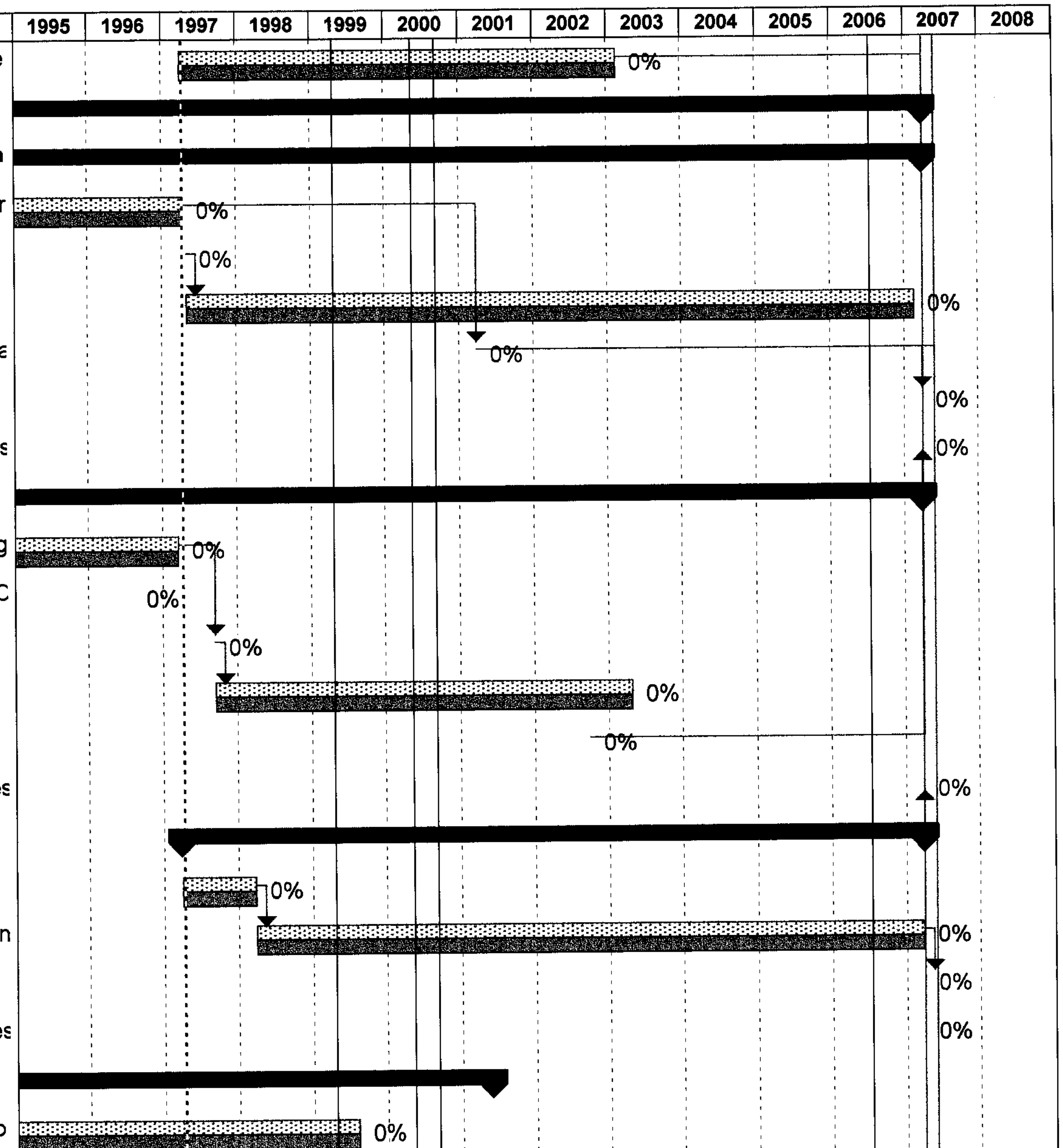
ID	WBS	Task Name
184	7.1.1.3.4	Integrate culture research results into analysis & guide
185	**7.1.1.4**	**Improve yields through breeding and testing**
186	**7.1.1.4.1**	**Improve SC yields through breeding & testing in SC region**
187	7.1.1.4.1.1	Round 1 breeding, screening & regional testing in SC r
188	7.1.1.4.1.2	Evaluate progress; modify breeding strategy
189	7.1.1.4.1.3	Round 2 breeding, screening, regional testing
190	7.1.1.4.1.4	first new SC biomass varieties released to seed compa
191	7.1.1.4.1.5	additional new varieties released to seed companies
192	7.1.1.4.1.6	Hand-off breeding to other agencies/private companies
193	**7.1.1.4.2**	**Improve NC yields through breeding & testing (2.07)**
194	7.1.1.4.2.1	Round 1 breeding, biomass screening, regional testing
195	7.1.1.4.2.2	1 new improved forage/biomass variety released in NC
196	7.1.1.4.2.3	Evaluate progress; modify breeding strategy
197	7.1.1.4.2.4	Round 2 breeding, screening, regional testing
198	7.1.1.4.2.5	1-2 new varieties released to seed companies
199	7.1.1.4.2.6	Hand-off breeding to other agencies/private companies
200	**7.1.1.4.3**	**Improve NE/Lake yields through breeding & testing (2.07)**
201	7.1.1.4.3.1	Germplasm collection
202	7.1.1.4.3.2	Round 1 breeding, yield screening & regional testing in
203	7.1.1.4.3.3	1-2 new varieties released in NE/L
204	7.1.1.4.3.4	Hand-off breeding to other agencies/private companies
205	**7.1.1.5**	**Develop physiology/biotechnology information**
206	7.1.1.5.1	Improve growth physiology understanding and links to



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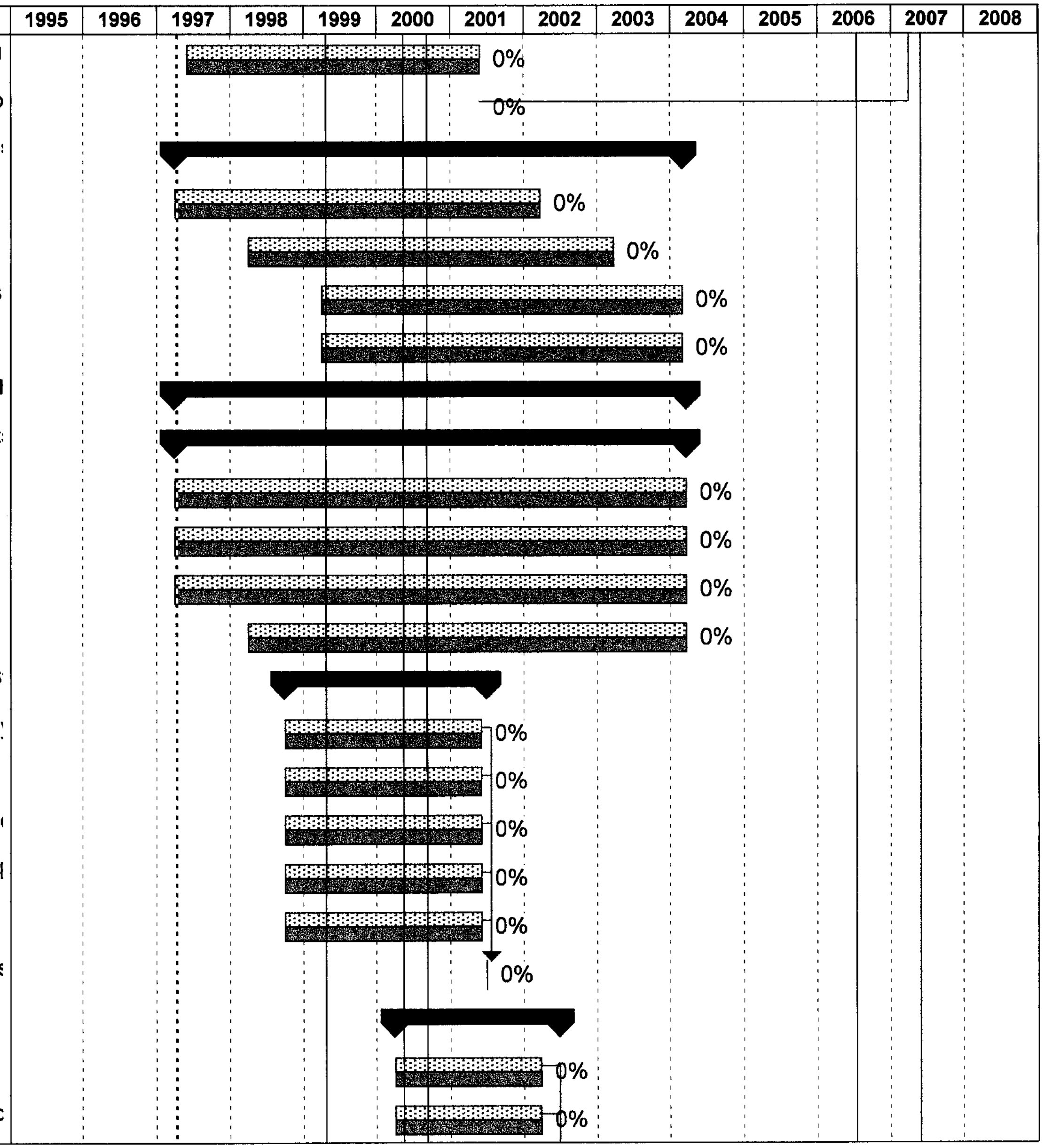
ID	WBS	Task Name
207	7.1.1.5.2	Develop enhanced breeding techniques based on tissu
208	7.1.1.5.3	Handoff information to breeding activities/private secto
209	**7.1.1.6**	**Assure sustainable yields by addressing pathogen & pest i:**
210	7.1.1.6.1	Use Iowa scale-up to monitor pathogens and pests
211	7.1.1.6.2	Monitor pathogens &pests in all additional scale-ups
212	7.1.1.6.3	Evaluate control mechanisms for pathogens and pests
213	7.1.1.6.4	Include pathogen/pest resistance in breeding efforts
214	**7.1.2**	**Reduce risks & expand expertise through scale-up researcl**
215	**7.1.2.1**	**Expand number and scale of switchgrass field R&D project:**
216	7.1.2.1.1	New plantings in Chariton Valley, Iowa (4000 acres)
217	7.1.2.1.2	New plantings in SC region (20-50 acres) (2.03)
218	7.1.2.1.3	New plantings in SE region (20-500 acres), (2.04)
219	7.1.2.1.4	New plantings in alternate region (20-50 acres)
220	**7.1.2.2**	**Improve Engineering of Switchgrass Harvest, Handling & S**
221	7.1.2.2.1	Test/modify existing large harvesters to handle higher ;
222	7.1.2.2.2	Test/modify existing small harvesters to handle higher
223	7.1.2.2.3	Identify best field storage & handling alternatives for N(
224	7.1.2.2.4	Identify best field storage & handling alternatives for Sl
225	7.1.2.2.5	Identify transportation & size reduction options
226	7.1.2.2.6	Provide information to assist partnership arrangements
227	**7.1.2.3**	**Perform economic and risk studies with scale-up data**
228	7.1.2.3.1	Evaluate yield and production cost variation data
229	7.1.2.3.2	Evaluate storage, handling, transportation cost variatic



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ID	WBS	Task Name
230	7.1.2.3.3	Evaluate financing and procurement strategies
231	7.1.2.3.4	Provide information to update business plans
232	**7.1.2.4**	**Monitor and document environmental effects**
233	7.1.2.4.1	Monitor soil quality changes across Iowa Scaleup
234	7.1.2.4.2	Document biodiversity and wildlife habitat effects in lov
235	7.1.2.4.3	Continue evaluating erosion & water quality effects in I
236	7.1.2.4.4	Monitor soil quality changes across second scale-up
237	7.1.2.4.5	Monitor regional level water quality effects of second s
238	7.1.2.4.6	Document biodiversity and wildlife habitat effects in se
239	7.1.2.4.7	Provide guidelines to demonstration project growers
240	**7.1.2.5**	**Establish switchgrass quality variation for ethanol convers**
241	7.1.2.5.1	Identify feedstock characteristics relevant to SSF enzy
242	7.1.2.5.2	Collect Samples from field trials representing range of
243	7.1.2.5.3	Analyze feedstock samples for effects on ethanol proce
244	7.1.2.5.4	Handoff information & samples to ethanol process R&I
245	**7.2**	**Biomass Conversion Technology**
246	**7.2.1**	**Softwood-specific process integration and process develop**
247	**7.2.1.1**	**Preliminary Technology Analysis**
248	**7.2.1.1.1**	**Investigate technologies**
249	7.2.1.1.1.1	SO2 steam explosion
250	7.2.1.1.1.2	Dilute acid hydrolysis
251	7.2.1.1.1.3	Concentrated acid
252	7.2.1.1.1.4	ACOS Organosolv process

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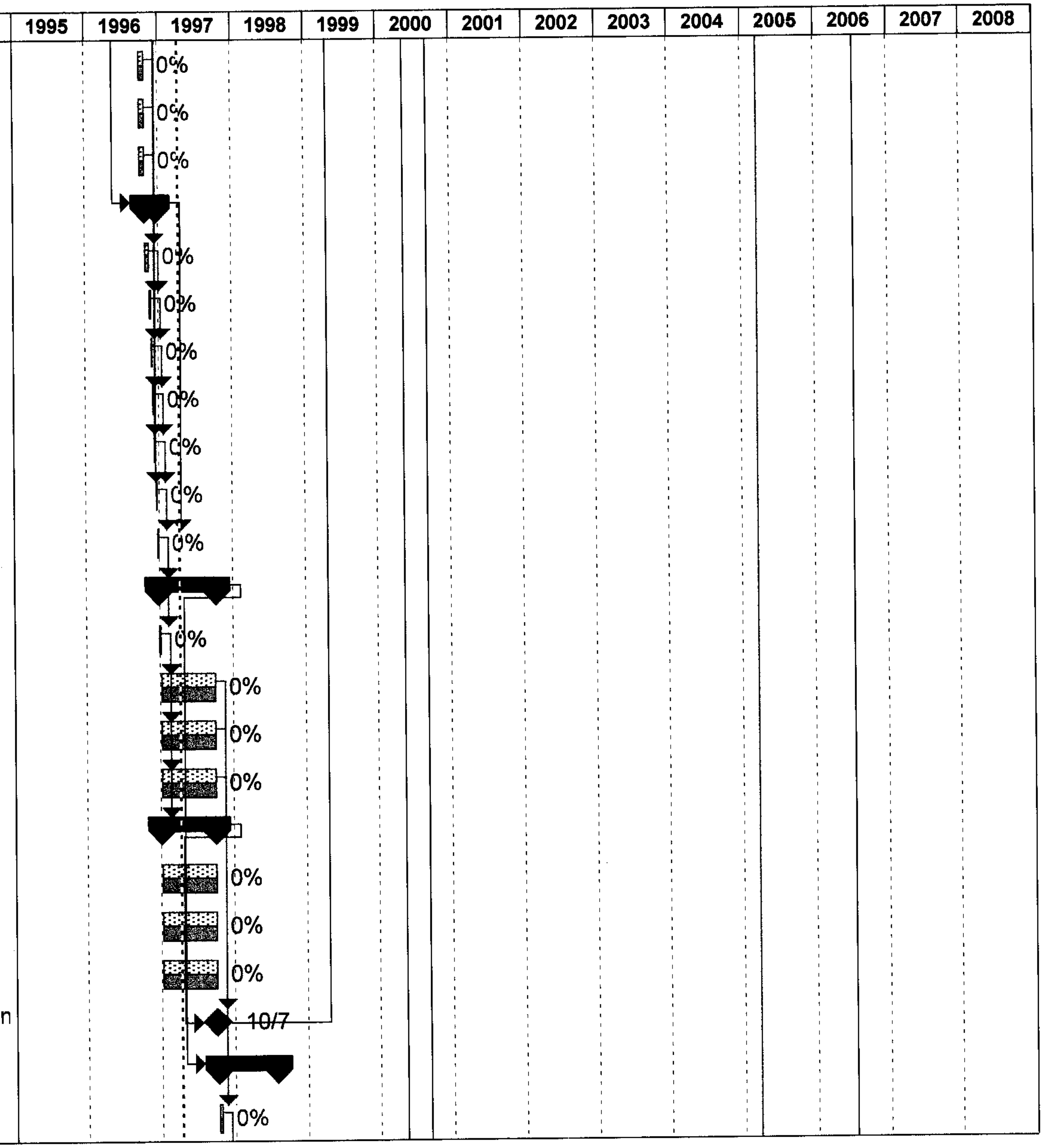
ID	WBS	Task Name
253	7.2.1.1.1.5	Enzyme production
254	7.2.1.1.1.6	Fermentation/SHF/SSF
255	7.2.1.1.1.7	Lignin utilization
256	**7.2.1.1.2**	**Model 5 process options for softwoods**
257	7.2.1.1.2.1	Complete process & economic model
258	7.2.1.1.2.2	Option A
259	7.2.1.1.2.3	Option B
260	7.2.1.1.2.4	Option C
261	7.2.1.1.2.5	Option D
262	7.2.1.1.2.6	Option E
263	7.2.1.1.3	Identify technology gaps
264	**7.2.1.2**	**Fill Technology Gaps for Softwoods**
265	7.2.1.2.1	Revise softwoods technology plan
266	7.2.1.2.2	Subcontract or CRADA with UBC
267	7.2.1.2.3	Subcontract #2
268	7.2.1.2.4	Subcontract #3
269	**7.2.1.2.5**	**Pretreatment & fermentation work at NREL**
270	7.2.1.2.5.1	Dilute acid pretreatment
271	7.2.1.2.5.2	SO2 Steam explosion
272	7.2.1.2.5.3	C6 Fermentation R&D
273	7.2.1.2.6	Preliminary assessment of integrated technologies con
274	**7.2.1.3**	**Process Selection and PDU Testing**
275	7.2.1.3.1	Revise Process Models



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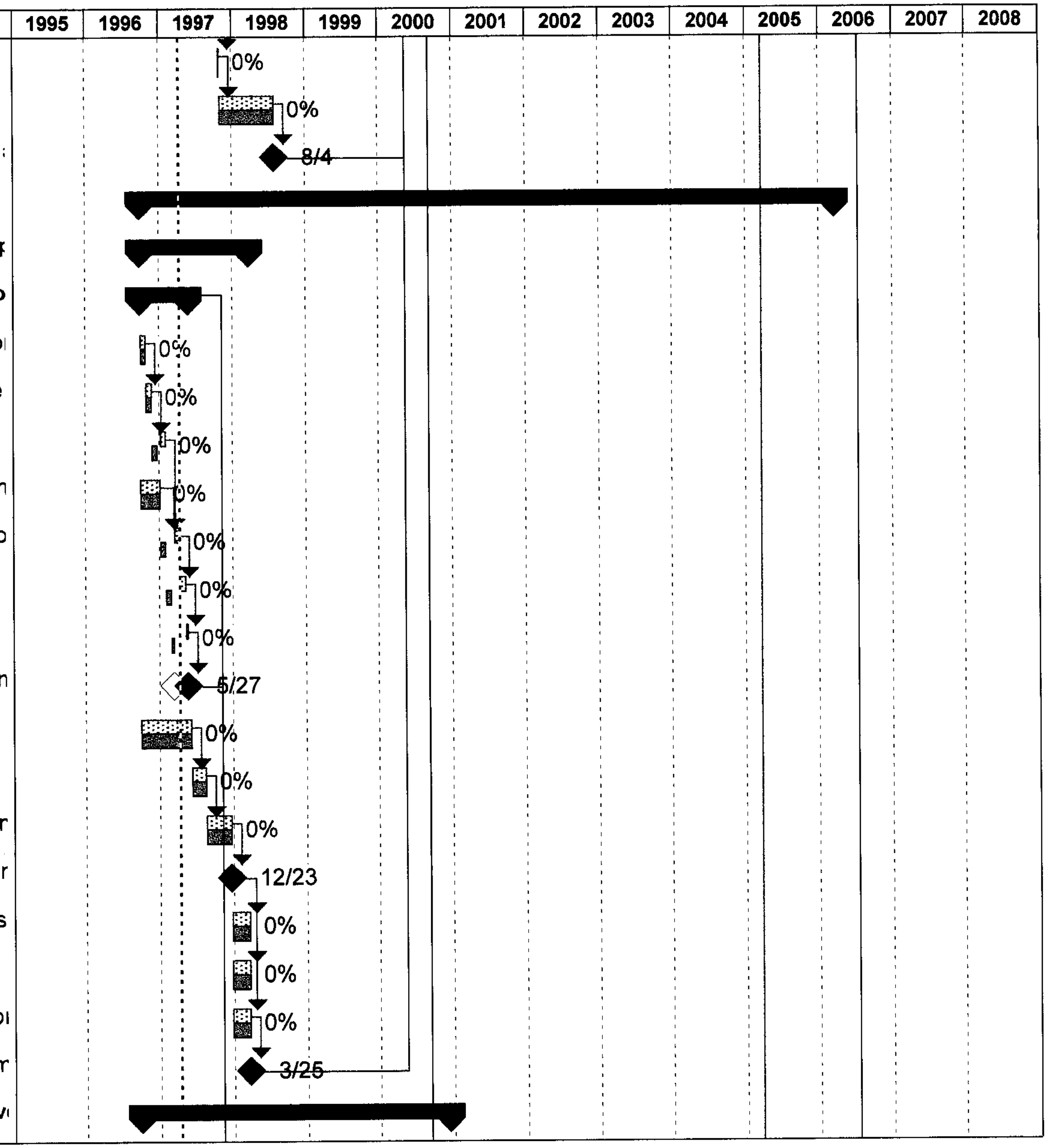
ID	WBS	Task Name
276	7.2.1.3.2	Select Process for further development
277	7.2.1.3.3	Subcontract #4
278	7.2.1.3.4	Integrated process for softwood to ethanol technology :
279	**7.2.2**	**Process Integration and Process Development**
280	**7.2.2.1**	**Provide commercial development facility capabilities to sup**
281	**7.2.2.1.1**	**Demonstrate an integrated process for ethanol from cellulo**
282	7.2.2.1.1.1	Establish complete integrated process flow diagram fo
283	7.2.2.1.1.2	Prove that aseptic conditions can be maintained in the
284	7.2.2.1.1.3	Obtain approval to operate the mini-pilot plant using a
285	7.2.2.1.1.4	Design, procure and test ion exchange equipment for h
286	7.2.2.1.1.5	Ready Sunds reactor to produce pretreated sawdust fo
287	7.2.2.1.1.6	Run process qualifier technology demonstration
288	7.2.2.1.1.7	Document process qualifier demonstration
289	7.2.2.1.1.8	Mini-pilot biochemical conversion unit available for con
290	7.2.2.1.2	Design full pilot plant scale detoxification equipment
291	7.2.2.1.3	Install full pilot plant scale detoxification equipment
292	7.2.2.1.4	Test and modify full pilot scale detoxification equipmer
293	7.2.2.1.5	Detoxification process available for pilot scale commer
294	7.2.2.1.6	Design SSCF system for pilot plant demonstration bas
295	7.2.2.1.7	Evaluate spent solids for combustion value
296	7.2.2.1.8	Investigate the impacts of gypsum on the bioethanol pı
297	7.2.2.1.9	Pilot scale testing capability available for use by comm
298	**7.2.2.2**	**Provide integrated process technology for commercial dev**



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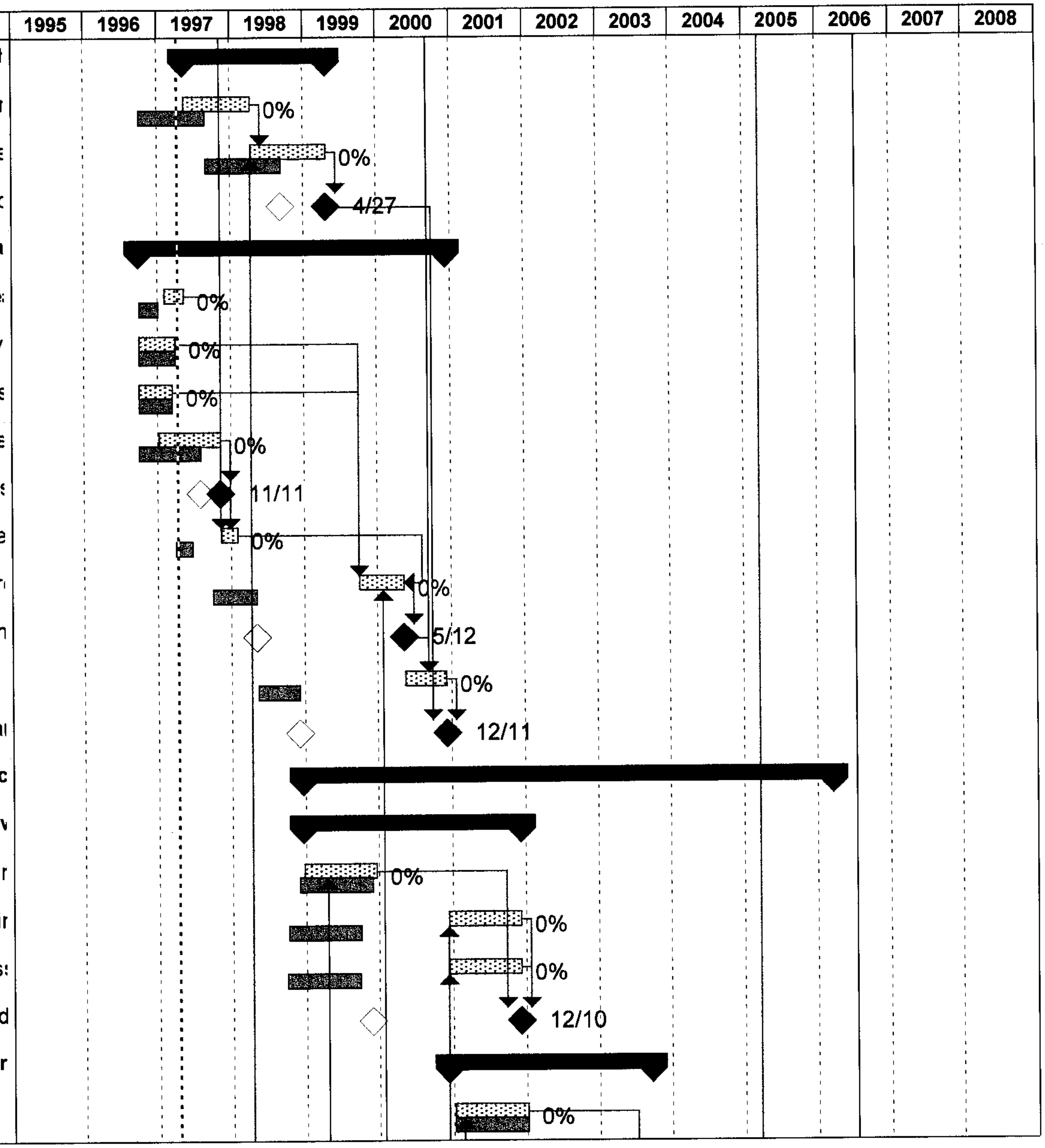
ID	WBS	Task Name
299	**7.2.2.2.1**	**Develop cellulase enzyme production technology utilizing l**
300	7.2.2.2.1.1	Establish cellulase production on hydrolysate and pretr
301	7.2.2.2.1.2	Improve cellulase production on hydrolysate and pretre
302	7.2.2.2.1.3	Cellulase enzyme production technology available for c
303	**7.2.2.2.2**	**Improve integrated process performance to achieve cost ta**
304	7.2.2.2.2.1	Produce pretreated and detoxified materials to meet te
305	7.2.2.2.2.2	Improve pretreatment to increase cellulose digestibility
306	7.2.2.2.2.3	Develop Zymomonas strain adapted to 100 % hydrolys
307	7.2.2.2.2.4	Complete detoxification process development at the be
308	7.2.2.2.2.5	Provide data on applicability of detoxification to various
309	7.2.2.2.2.6	Investigate SSCF performance by consideration of alte
310	7.2.2.2.2.7	Investigate SSCF performance utilizing improved pretr
311	7.2.2.2.2.8	Improved process technology ready for review and gen
312	7.2.2.2.2.9	Prioritized improvement projects carried out
313	.2.2.2.2.10	Integrated biomass to ethanol technology meeting yea
314	**7.2.2.3**	**Test incremental improvements under integrated process c**
315	**7.2.2.3.1**	**First roll-out of improvements in technology for near term v**
316	7.2.2.3.1.1	Test first generation countercurrent prehydrolysis techr
317	7.2.2.3.1.2	Test Phase I genetically engineered cellulase system ir
318	7.2.2.3.1.3	Test improved Zymomonas strain in integrated proces:
319	7.2.2.3.1.4	Documented improvements available for commercial d
320	**7.2.2.3.2**	**Second roll-out of improvements in technology for near ter**
321	7.2.2.3.2.1	Test lignin utilization technology



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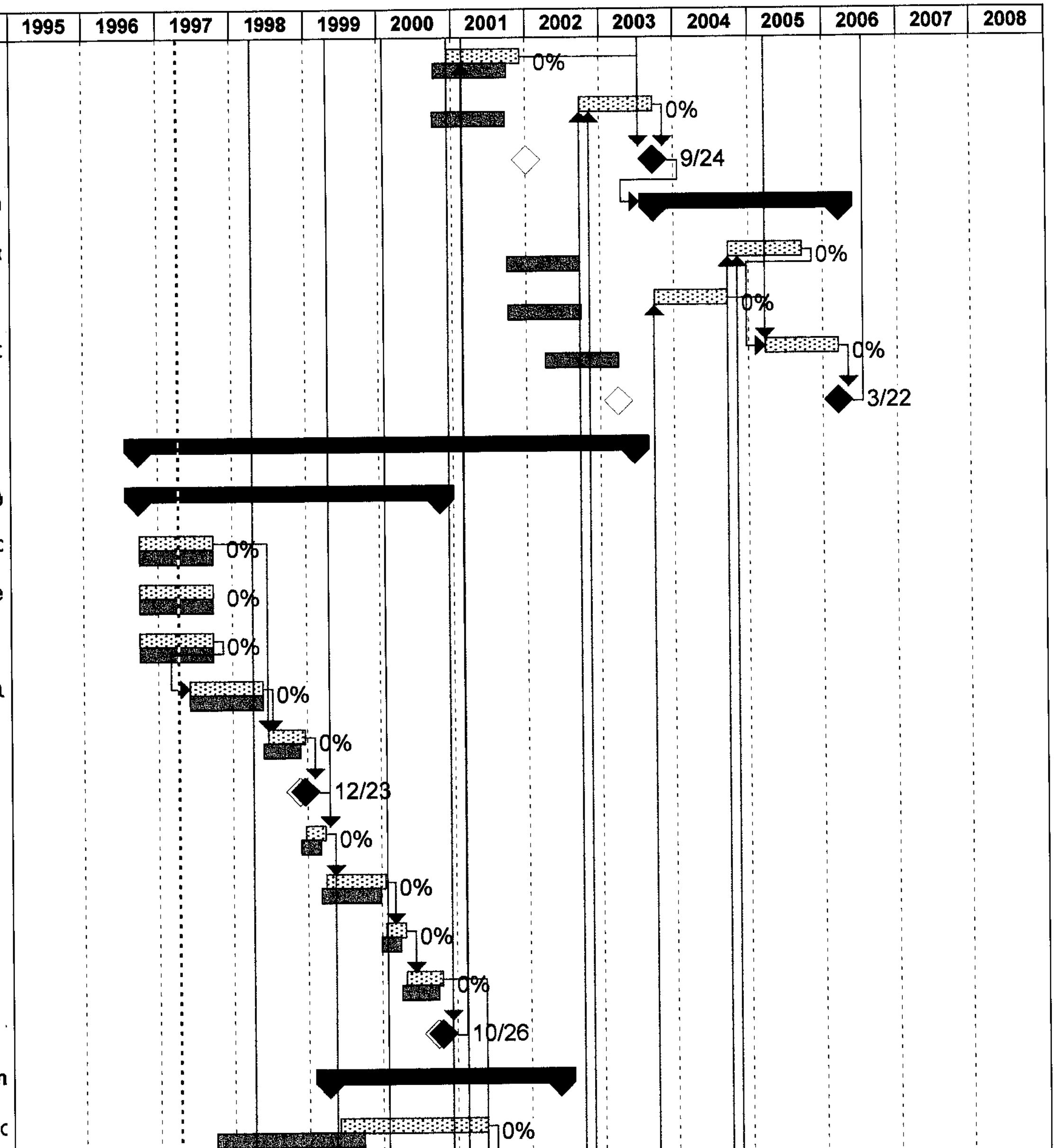
ID	WBS	Task Name
322	7.2.2.3.2.2	Test second generation countercurrent prehydrolysis te
323	7.2.2.3.2.3	Test "super" Zymomonas strain (robust) and/or Lactob
324	7.2.2.3.2.4	Improved low-value feedstock technology available for
325	**7.2.2.3.3**	**Develop integrated process for switchgrass conversion tha**
326	7.2.2.3.3.1	Test improvements in fermentor strains at the bench sc
327	7.2.2.3.3.2	Test Phase II cellulase system at the bench scale
328	7.2.2.3.3.3	Integrate switchgrass to ethanol process at smallest pc
329	7.2.2.3.3.4	Switchgrass technology available for commercial deve
330	**7.2.3**	**Chemical Hydrolysis R&D**
331	**7.2.3.1**	**Develop countercurrent chemical prehydrolysis technology**
332	7.2.3.1.1	Bench scale development of countercurrent chemical p
333	7.2.3.1.2	Supply test quantities of pretreated feedstocks for othe
334	7.2.3.1.3	Design and procure a prototype reactor
335	7.2.3.1.4	Modify, expand PDU and install and shakedown all equ
336	7.2.3.1.5	Test and modify prototype reactor
337	7.2.3.1.6	Hand-off prototype to EPD for integrated testing
338	7.2.3.1.7	Design second generation reactor
339	7.2.3.1.8	Procure second generation reactor
340	7.2.3.1.9	Install and shakedown second generation unit
341	7.2.3.1.10	Test and modify second generation unit
342	7.2.3.1.11	Hand-off second generation unit to EPD for integrated
343	**7.2.3.2**	**Develop countercurrent complete chemical hydrolysis tech**
344	7.2.3.2.1	Bench scale development of countercurrent complete c



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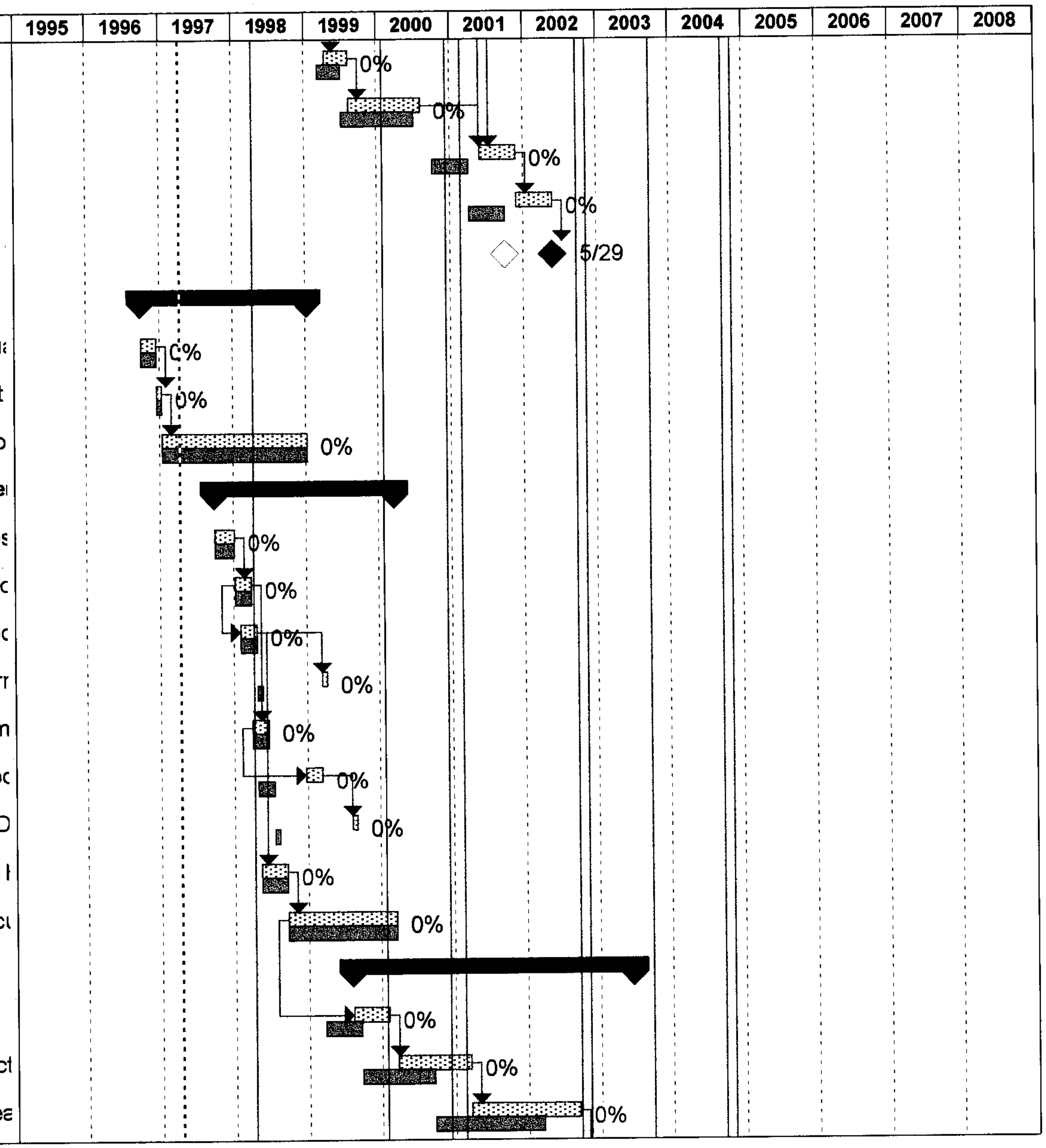
ID	WBS	Task Name
345	7.2.3.2.2	Design complete hydrolysis reactor
346	7.2.3.2.3	Procure complete hydrolysis reactor
347	7.2.3.2.4	Install and shakedown complete hydrolysis reactor
348	7.2.3.2.5	Initial testing of complete hydrolysis reactor
349	7.2.3.2.6	Hand-off second generation unit to EPD for integrated
350	**7.2.3.3**	**Alternate Pretreatment Evaluation**
351	7.2.3.3.1	Complete Data Analysis and Process Economic Evalu:
352	7.2.3.3.2	Develop Strategy for Follow-on Alternate Pretreatment
353	7.2.3.3.3	Further Development/Scale up/Testing of Selected Pro
354	**7.2.3.4**	**Long Term Feedstock (Hardwood) Bench Scale Developme**
355	7.2.3.4.1	Identify and Obtain Representative Hardwood Samples
356	7.2.3.4.2	Determine Countercurrent Prehydrolysis Parameters fc
357	7.2.3.4.3	Determine Best Available Detox Methods for Hardwooc
358	7.2.3.4.4	Quantify Material Balance, Solids Digestibility and Ferr
359	7.2.3.4.5	Determine Countercurrent Complete Hydrolysis Param
360	7.2.3.4.6	Determine Best Available Detox Methods for Hardwooc
361	7.2.3.4.7	Quantify Material Balance and Fermentability of Std. D
362	7.2.3.4.8	Conduct Preliminary Process Engineering Analysis of I
363	7.2.3.4.9	Scale up Modification/Testing in Appropriate Counterci
364	**7.2.3.5**	**Long Range Advanced Pretreatment Technologies**
365	7.2.3.5.1	Identify Advanced Pretreatment Technologies
366	7.2.3.5.2	Conduct Bench Scale Development Program on Select
367	7.2.3.5.3	Identify and Obtain Appropriate Engineering Scale Rea



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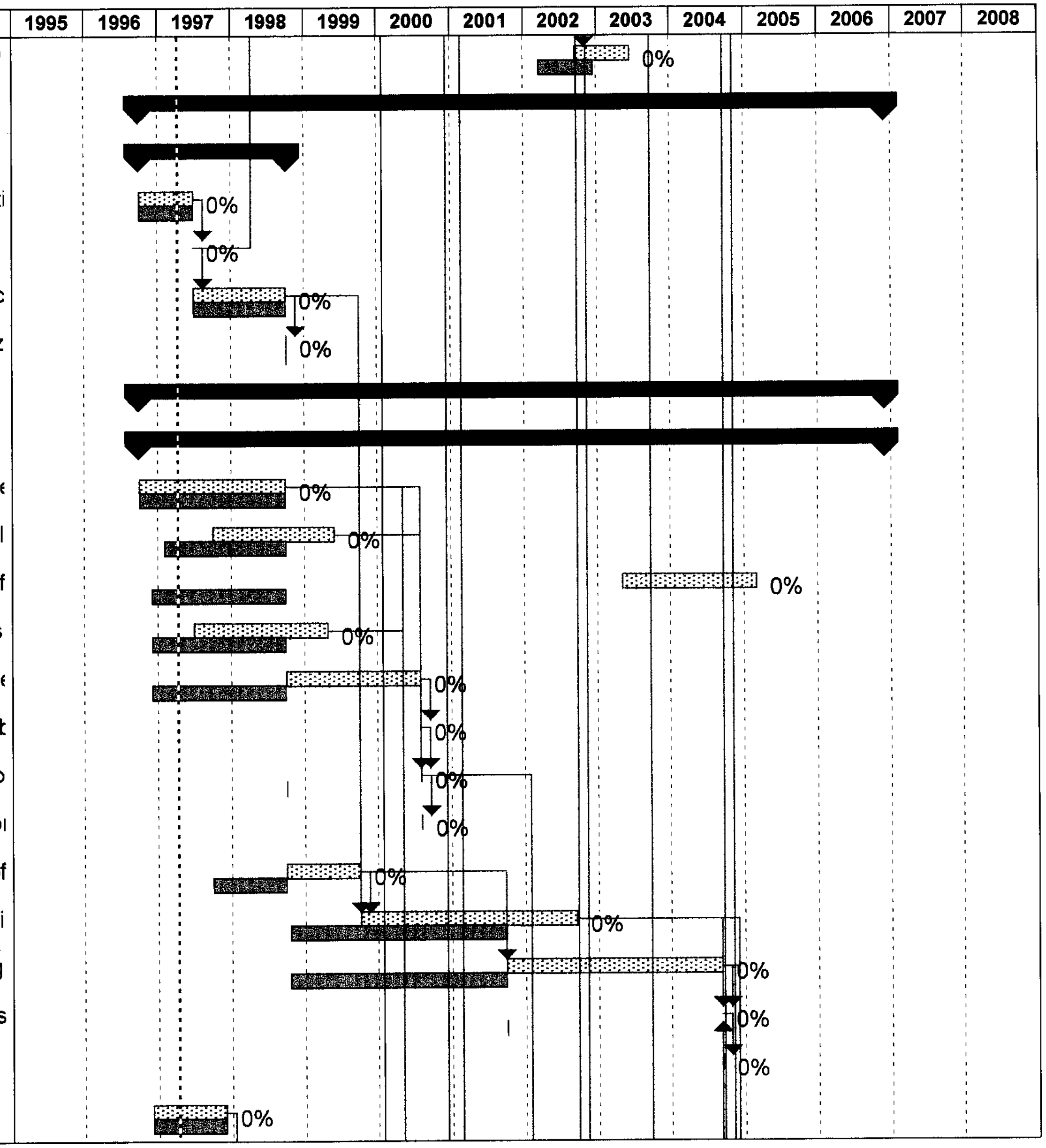
ID	WBS	Task Name
368	7.2.3.5.4	Testing of Advanced Pretreatment Technologies at PD
369	**7.2.4**	**Enzyme Technology R&D**
370	**7.2.4.1**	**Near Term Enzyme R&D**
371	7.2.4.1.1	T. reesei: Decrease cellulase cost by optimizing inducti
372	7.2.4.1.2	Deliver new protocols to EPD
373	7.2.4.1.3	T. reesei: Determine effects of induction protocols on c
374	7.2.4.1.4	Report correlation between T. reesei induction and enz
375	**7.2.4.2**	**Mid Term Enzyme R&D**
376	**7.2.4.2.1**	**Develop cost effective enzyme system for pretreated SG**
377	7.2.4.2.1.1	Phase I: Improve action of EI on pSG using site-directe
378	7.2.4.2.1.2	Phase I: Increase Topt and process tolerance of CBH I
379	7.2.4.2.1.3	Perform substrate/cellulose binding domain modeling f
380	7.2.4.2.1.4	Phase I: Increase Topt and process tolerance of E3 us
381	7.2.4.2.1.5	Provide high resolution x-ray structure for E3 and clone
382	7.2.4.2.1.6	Report K Milestone describing cellulase improvement t
383	7.2.4.2.1.7	Deliver Phase I engineered cellulase system to EPD fo
384	7.2.4.2.1.8	DECISION: Pick plant or submerged culture expressio
385	7.2.4.2.1.9	Develop strategy to improve active site performance of
386	.2.4.2.1.10	Phase II: Increase specific activity of CBHI on pSG usi
387	.2.4.2.1.11	Phase II: Increase specific activity of E3 on pSG using
388	.2.4.2.1.12	Deliver Phase II engineered cellulase system w access
389	.2.4.2.1.13	DECISION: Pick enzymes or DMC
390	.2.4.2.1.14	Produce rEI, rCBHI, and rE3 in 1st Gen plants



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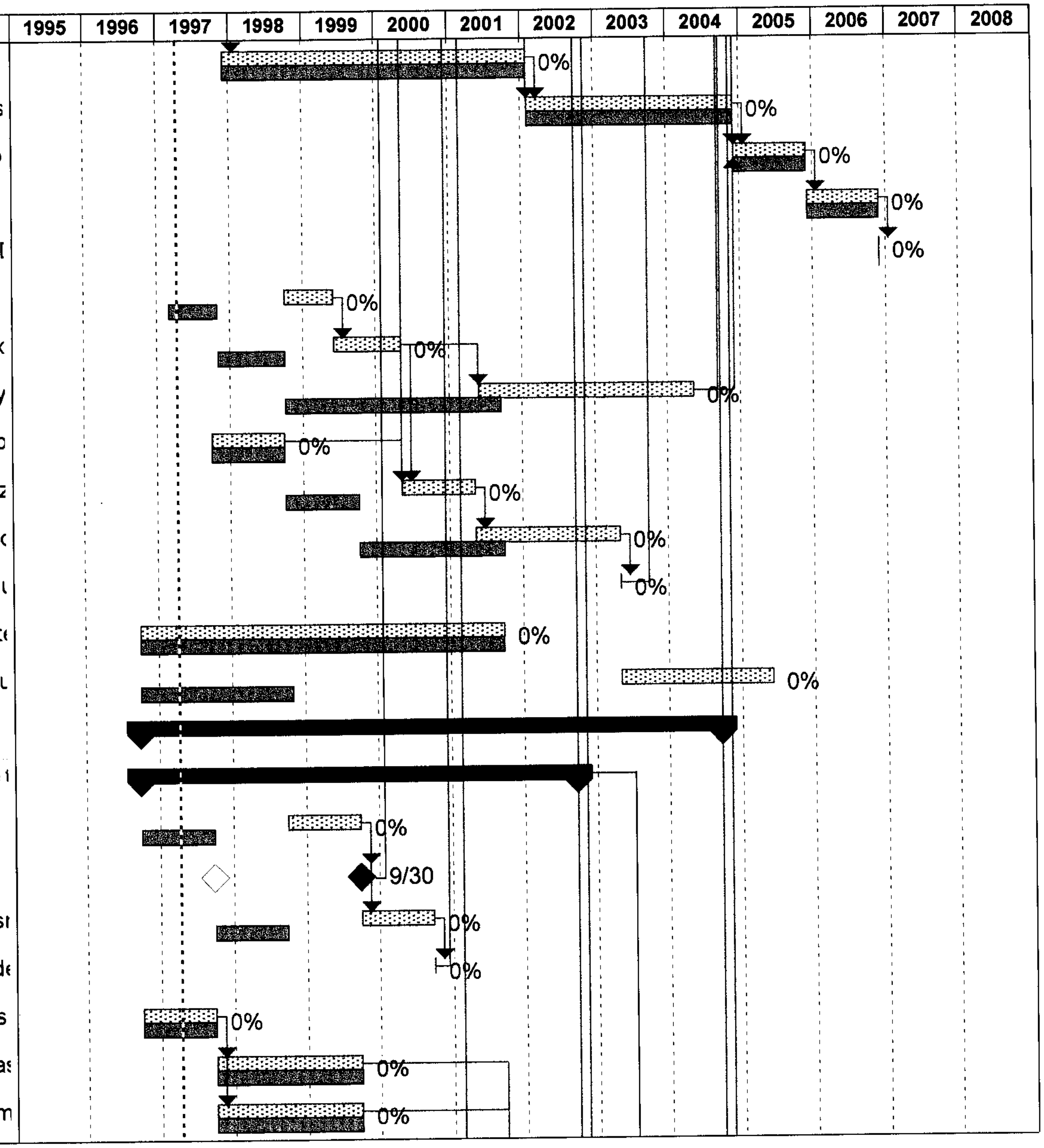
ID	WBS	Task Name
391	.2.4.2.1.15	Evaluate field tests and enzyme recovery schemes
392	.2.4.2.1.16	Produce rEI, rCBHI, and rE3 in 2nd Gen plant systems
393	.2.4.2.1.17	Produce improved rEI, rCBHI, and rE3 in best field cro
394	.2.4.2.1.18	Evaluate field tests and enzyme recovery schemes
395	.2.4.2.1.19	Deliver technology for plant produced cellulases to EPI
396	.2.4.2.1.20	Provide purified accessory enz for testing at NREL
397	.2.4.2.1.21	Determine utility of accessory enz (xylanases, cellodex
398	.2.4.2.1.22	Improve Topt and process tolerance of accessory enzy
399	.2.4.2.1.23	Produce rEI, rCBHI, and E3 in submerged culture (Asp
400	.2.4.2.1.24	Produce Phase I rEI, rCBHI, rE3, and/or accessory enz
401	.2.4.2.1.25	Evaluate Gen II submerged culture production technolc
402	.2.4.2.1.26	Deliver mature technology for submerged culture produ
403	.2.4.2.1.27	Evaluate new engineered cellulase/accessory enz syst
404	.2.4.2.1.28	Evaluate enzymes expressed from best plant and/or su
405	**7.2.5**	**Fermentation Organism Development**
406	**7.2.5.1**	**Develop Zymomonas Organism for use in year 2000 waste**
407	7.2.5.1.1	Evaluate new new Zymomonas strains
408	7.2.5.1.2	Select strains for hand-off to integration studies
409	7.2.5.1.3	Develop further improvements to Zymomonas organis
410	7.2.5.1.4	Hand-off improved Zymomonas strain for pilot scale de
411	7.2.5.1.5	Investigate new approaches to improving Zymomonas
412	7.2.5.1.6	Begin making metabolic enhancements of Zymomonas
413	7.2.5.1.7	Implement strategies to improve robustness of Zymom



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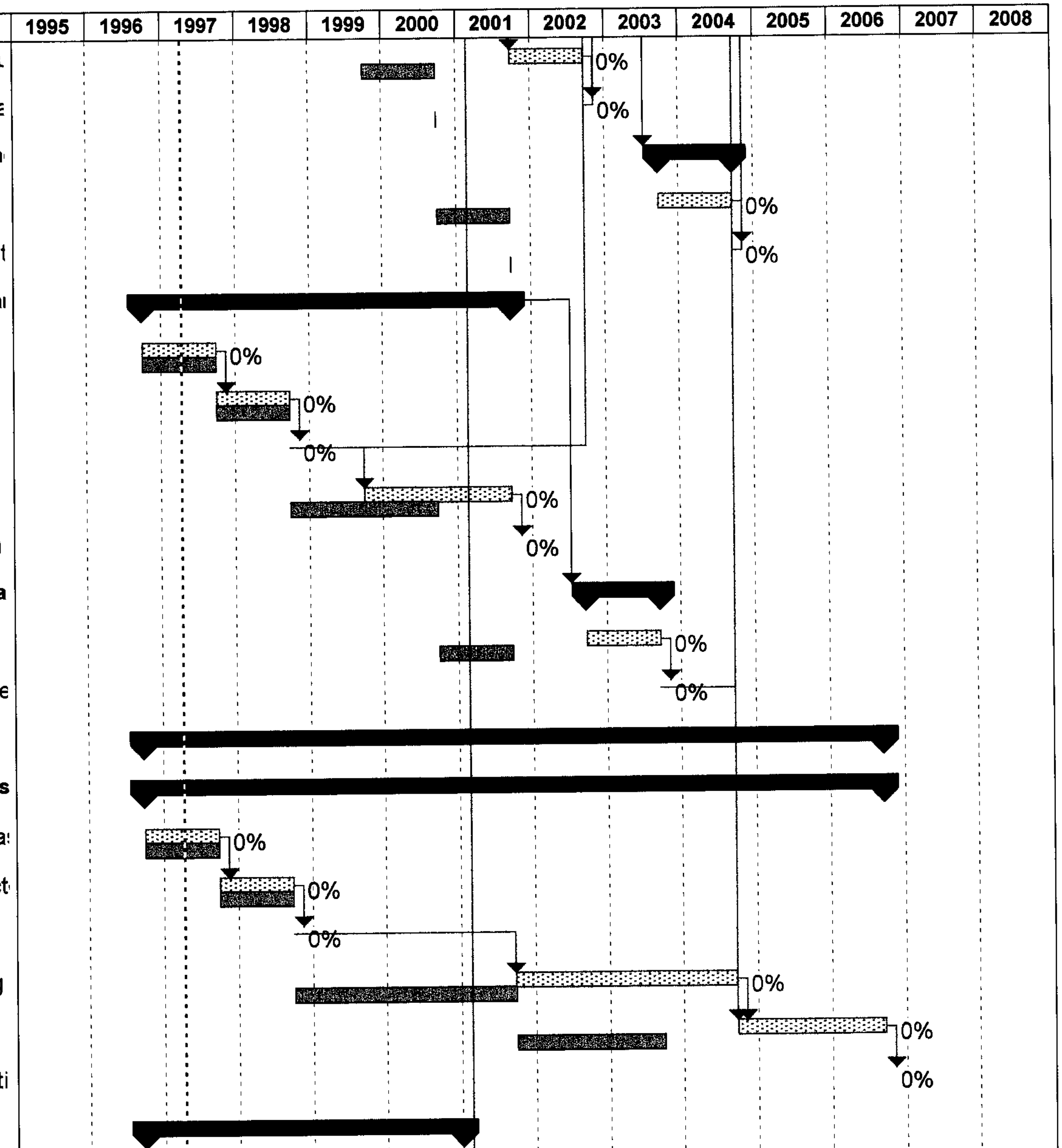
ID	WBS	Task Name
414	7.2.5.1.8	Develop a "super" Zymomonas strain with desired robu
415	7.2.5.1.9	Hand-off advanced Zymomonas strains to industrial pa
416	**7.2.5.2**	**Develop Zymomonas Organism for use in year 2005 switch**
417	7.2.5.2.1	Make adjustments switchgrass
418	7.2.5.2.2	Hand-off switchgrass Zymomonas strain to EPD for int
419	**7.2.5.3**	**Develop a Lactobacillus strain for improved performance ai**
420	7.2.5.3.1	Re-initiate work on lactobacillus
421	7.2.5.3.2	Develop an ethanol producing lactobacillus
422	7.2.5.3.3	Hand-off lactobacillus to EPD for integration and PDU
423	7.2.5.3.4	Assess and improve lactobacillus strains
424	7.2.5.3.5	Hand-off lactobacillus organism to EPD for integration
425	**7.2.5.4**	**Develop Lactobacillus strain for use in year 2005 switchgra**
426	7.2.5.4.1	Make adjustments for switchgrass sugars as needed
427	7.2.5.4.2	Hand-off switchgrass Lactobacillus strain to EPD for te
428	**7.2.6**	**Direct Microbial Conversion Strain Development**
429	**7.2.6.1**	**Develop cost effective Zymomonas strains for DMC proces**
430	7.2.6.1.1	Acquire or produce cDNA clone of best beta-glucosida
431	7.2.6.1.2	Clone cellobiase in best "Z" using best expression vect
432	7.2.6.1.3	Deliver cellobiose fermenting "Z" to EPT for testing
433	7.2.6.1.4	Develop integrated transformation system for Z, using
434	7.2.6.1.5	Clone rEI and rCBHI in best "Z" or Lactobacillus
435	7.2.6.1.6	Deliver engineered "Z" or Lactobacillus to EPT for testi
436	**7.2.7**	**Lignin Utilization R & D**



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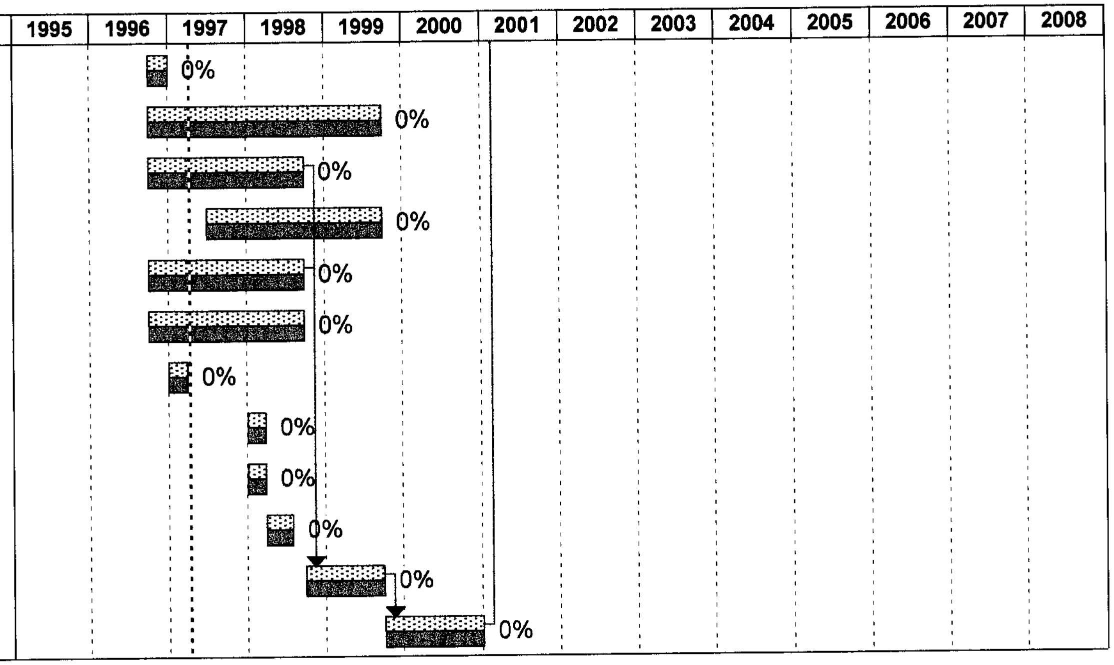
ID	WBS	Task Name
437	7.2.7.1	Technoeconomic analysis
438	7.2.7.2	Lab optimization of BCD
439	7.2.7.3	Reproducibility and batch scale-up
440	7.2.7.4	Supply lignin to Utah, Sandia and NREL
441	7.2.7.5	Jet reactor BCD process work
442	7.2.7.6	Analysis of BCD products
443	7.2.7.7	Detailed flow diagram: BCD/HPR
444	7.2.7.8	Detailed flow diagram:E+SHR
445	7.2.7.9	Evaluation/ determine product targets
446	7.2.7.10	Technoeconomic analysis of best products
447	7.2.7.11	Scale-up of jet or other reactor
448	7.2.7.12	Pilot plant testing of new reactor



12. Glossary

Name	Description
ACOS process	Acid Catalyzed Organosolv Saccharification process.
AFUF	Alternative Fuels User Facility. A pilot plant located at the National Renewable Energy Laboratory in Golden, Colorado intended for use by industrial clients interested in commercializing bioethanol technology.
ASPEN™ process simulation	A steady-state chemical process software tool used to model performance of the bioethanol process.
Baseline Plan	The multi-year plan for bioethanol as established in October 1996
Bioethanol	A recent term coined to distinguish ethanol from lignocellulosic biomass, as opposed to traditional crops such as corn
Biofuels Program	The U.S. Department of Energy's program for development of renewable, biomass-derived transportation fuels
Biomass Power Program	The U.S. Department of Energy's program for development of renewable, biomass-derived electricity.
BL-1-LS	A Biosafety containment standard for genetically engineered organisms. Production or R&D facilities handling genetically engineered organisms are required to meet standards for operation prior to introduction of recombinant organisms covered at this relatively low safety hazard standard.
BOD	Biological Oxidation Demand.
Business plan	Plan based on specific negotiated contracts for feedstock and fuel supply. Supported by pilot scale data and detailed design and economics for proposed demonstration plant. Anticipated cost of this effort is around $2 million
CBD	Cellulose Binding Domain
CBH I	Cellobiohydrolase I
Cellulase	A collection of enzymes capable of hydrolyzing cellulose to its component sugars

Complete Hydrolysis	Thermochemical processing of biomass to release wood sugars from hemicellulose and cellulose biopolymers for conversion to ethanol.
Core technology	Technology for production of biomass feedstocks and conversion of biomass to ethanol applicable to energy crops. It includes process technology which can utilize both hemicellulose and cellulose-derived sugars.
CRADA	Cooperative Research and Development Agreement
Critical path	A series of tasks which, if delayed, will cause a delay in the timing of the completion of a project
CRP	Conservation Reserve Program. Refers to land qualifying for subsidized "set-aside" by the U.S. Department of Agriculture
CSBR	Continuous Shrinking Bed Reactor.
Demonstration Plant	Large scale operation intended to prove commercial viability of bioethanol technology. Large scale implies production capability of several million gallons per year or higher
Detoxification	Process for removing unwanted byproducts from prehydrolysis or hydrolysis of biomass which can inhibit fermentative conversion of sugars to ethanol.
Dilute Acid Hydrolysis	Thermochemical process using inorganic acids to catalyze hydrolysis of hemicellulose and cellulose.
DMC	Direct Microbial Conversion. Process in which a single organism is used to achieve hydrolysis and fermentation of biomass components to ethanol
DOE	Also "U.S. DOE". U.S. Department of Energy
E1	A cellulase enzyme known as Endoglucanase 1 isolated from a thermophilic bacterium
E3	A cellulase enzyme known as Endoglucanase 3 isolated from a thermophilic bacterium
Enzyme Induction	Protocol for forcing microorganisms to produce an enzyme.
EPD	Ethanol Process Development team
Ethanologen	Ethanol-producing microorganism

Feasibility Study	Also "Final Feasibility Study." Detailed economics and more thorough lab scale studies intended to provide go/no go decision on detailed business plan. Anticipated costs of several hundred thousand dollars.
FPU	Filter Paper Unit. An arbitrarily defined unit for describing activity of cellulase enzymes based on the rate of degradation of cellulose filter paper.
Gantt Chart	Chart showing tasks as bars on a timeline in which relationships among the tasks can be shown.
GIS	Geographic Information System. Map-structured databases.
Grain Processing Wastes	Spent grain from processes such as brewing or other grain refining operations.
Gypsum	Calcium sulfate byproduct formed after lime neutralization of dilute sulfuric acid-pretreated biomass.
Hardwoods	Trees in the Dicotyledoneae class from which includes plants that may constitute the long term source of energy crops for the Biofuels Program.
Hydrolysate	Liquid phase product from thermochemical processing of biomass to release.
Lactobacillus	A possible future host for ethanol production. Lactobacillus is a lactic acid producing bacterium known for its robustness.
Lignin	The complex polyaromatic biopolymer that constitutes the structural backbone of plants and trees.
Mannan	A biopolymer of mannose sugar molecules.
Model Feedstock	A biomass feedstock used to develop fundamental process options for conversion of biomass to ethanol
MSW	Municipal Solid Waste. Solid waste collected for disposal in landfills or via incineration.
MYTP	Multi-Year Technical Plan.
NEPA	National Environmental Protection Act
Niche feedstocks	Biomass feedstocks available in smaller markets that do not have significant potential for supporting fuel production at the scale required to meet DOE fuel displacement goals.

NREL	National Renewable Energy Laboratory
OFD	U.S. Department of Energy Office of Fuels Development
ORNL	Oak Ridge National Laboratory
Overliming	Treatment of hydrolysate from intended to remove toxic compounds by increasing pH of the hydrolysate to alkaline conditions, returning to the hydrolysate to neutral or lower pH and removing precipitates that corm.
PDT	Partnership Development Team
PDU	Pilot Development Unit. Pilot plant capable of at least 1 ton per day of lignocellulosic biomass throughput for production of bioethanol
Prefeasibility Study	Also "Preliminary Feasibility." Screening study intended to determine most likely process options and preliminary economics for bioethanol production opportunities. It can involve limited lab scale studies in conjunction technoeconomic modeling and literature reviews. Outcome is go/no go decision on conducting final feasibility study. Anticipated costs of under $100,000.
Prehydrolysis	Thermochemical processing of biomass to release hemicellulosic fraction of biomass and increase accessibility of wood sugars to further attack and conversion to ethanol
Pretreated Solids	Solid phase containing primarily cellulose and lignin after hydrolysis to release hemicellulose from biomass.
Pretreatment	Refers to thermochemical process used to improve accessibility of cellulose and hemicellulose to hydrolysis and conversion to ethanol. Sometimes synonymous with prehydrolysis.
Process Integration	Bench and/or pilot scale operation of a complete process for conversion of biomass to ethanol.
Process Qualifier	Test intended to demonstrate ability to run a conversion technology from beginning to end and establish basic performance data.
rCBH I	Recombinant Cellobiohydrolase I, a cellulase enzyme
rE1	Recombinant version of the Endoglucanase 1cellulase enzyme

rE3	Recombinant version of the Endoglucanase 3 cellulase enzyme
Resource Loading	The process of assignment the amount of resources required to support the tasks within the plan.
SDM	Site-Directed Mutagenesis. Genetic engineering technique in which specific amino acids in an enzyme's protein structure are changed to try to cause improvements in enzyme performance
SHF	Separate Hydrolysis and Fermentation. Refers to a processes for conversion of lignocellulose to ethanol in which hydrolysis of the cellulose is done in a separate reactor from the fermentation step
SO_2 Steam Explosion	A pretreatment process for biomass
Spent Solids	Solids remaining after conversion of biomass to ethanol and recovery of ethanol product
SRWC	Short Rotation Woody Crops. Fast-growing trees for energy production.
SSCF	Simultaneous Saccharification and CoFermentaiton. Same as SSF only the term co-fermentation refers to the ability to ferment multiple types of sugars in one reactor system.
SSF	Simultaneous Saccharification and Fermentation. Refers to a process in which the hydrolysis of cellulose to sugar and the fermentation of these sugars to ethanol occurs in a single reactor.
STD	Strain Development Team
Sunds® reactor	Reactor system for themochemically treating biomass by introducing steam and dilute acid to biomass under controlled conditions of temperatire and retention time.
T. reesei	Trichoderma reesei. The fungal strain first discovered to have cellulose-hydrolytic capability. It is the parent strain of many of today's commercial strains used to produce cellulase enzymes.
Tactical Goal	High level goals for the program. In this plan, these are near and mid term goals for commercial deployment.
USDA	U.S. Department of Agriculture

USDA/ARS	U.S. Department of Agriculture/Agricultural Research Service
Waste cellulose feedstocks	Biomass feedstocks from existing operations assumed to be value at under $15 per dry ton
Xylan	A major component of hemicellulose. Biopolymer of the five carbon sugar xylose.
Zymomonas mobilis	Or, Zymomonas. An naturally occurring bacterium capable of highly efficient ethanol production which has been used as a host for genetic engineering work at NREL to improve and expand its capability to convert a range of sugars to ethanol.